1949

Stress distribution in two circular cylinders intersecting at right angles under the influence of internal pressure

Harmon, Leonard Edward

Pasadena, California; California Institute of Technology

GALCIT REPORT NO.________

GUGGENHEIM AERONAUTICAL LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

STRESS DISTRIBUTION IN TWO CIRCULAR CYLINDERS INTERSECTING AT RIGHT ANGLES UNDER THE INFLUENCE OF INTERNAL PRESSURE

Thesis by

Commander Leonard E. Harmon, U. S. Navy

PASADENA, CALIFORNIA

FORM AL-5 6M 2-49

STRESS DISTRIBUTION IN TWO CIRCULAR CYLINDERS INTERSECTING AT RIGHT ANGLES UNDER THE INFLUENCE OF INTERNAL PRESSURE

Thesis by

Commander Leonard E. Harmon, U. S. Navy

In Partial Fulfillment of the Requirements
For the Degree of
Aeronautical Engineer

California Institute of Technology
Pasadena, California

1949

ACKNOWLEDGEMENT

The author is indebted to Dr. Ernest E. Sechler, Professor of Aeronautics, California Institute of Technology, chairman of the supervising committee, for his valuable guidance in the formulation of this thesis, and to Dr. Yuan C. Fung, Research Fellow in Aeronautics, and Dr. George W. Housner, Assistant Professor of Applied Mechanics, other members of the supervising committee for the helpful comments and suggestions offered. He is also grateful to Mr. William H. Bowen, Superintendent, Guggenheim Aeronautical Laboratory, California Institute of Technology for his able assistance and advice in the procurement and preparation of the test specimens and testing equipment.

Further indebtedness is acknowledged to Lieutenant Commander Vernon E. Teig, U. S. Navy who collaborated in conducting the experiments and in the preparation of all tables and graphs presented herein.

ABSTRACT

This investigation is an experimental study of the stress distribution in two circular cylinders intersecting at right angles and acted on by internal pressure. Two specimens of the thick-wall category were tested to rupture and a strain gage analysis was made of critical points. The specifications of the specimens tested were so chosen that this investigation would be the logical beginning of an overall study of intersecting cylinders under the influence of internal pressure.

The results of two tests are insufficient to indicate trends or establish facts as conclusive. The conclusions reached as a result of this investigation are, therefore, of such a nature as to require confirmation by subsequent continuation of this study. These conclusions are:

1. The maximum stresses present in specimens of the type tested are in the plane of intersection and tangent to the ellipse of intersection at a point approximately fifteen degrees from the crotch.

2. Additional resistance to the high stresses at the plane of intersection is necessary over that required in the wall of a straight pipe.

3. Bending associated with the stressing of this type of intersection by the application of internal pressure is of minor importance in specimens in the thick wall range.

All the tests were made in collaboration with Lieutenant Commander Vernon E. Teig, U. S. Navy in the Structures Laboratory, Guggenheim Aeronautical Laboratory, California Institute of Technology, Pasadena, California, during the school year 1948-49.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF TABLES (Cont'd)

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

EXPLANATION OF SYMBOLS

E	Young's Modulus of Elasticity (assumed as 30,000,000 psi)
R	Strain Gage Reading
a and R	Internal Radius of Pipe (inches)
b	External Radius of Pipe (inches)
k	Strain Gage Constant (-200)
p	Internal Pressure (psi)
t	Thickness of Pipe (inches)
ϵ_a	Axial Strain (in/in)
ϵ_r	Radial Strain (in/in)
ϵ_t	Tangential Strain (in/in)
ϵ_1	Principal Strain (in/in)
σ_a	Axial Stress (psi)
σ_r	Radial Stress (psi)
σ_t	Tangential Stress (psi)
$\sigma_{1,2}$	Principal Stresses (psi)
μ	Poisson's Ratio (assumed to be 0.3)

INTRODUCTION

This investigation represents the first phase of a thorough study of the stress distribution in two intersecting circular cylinders under internal pressure being undertaken by the California Institute of Technology. In this phase all specifications of the specimens were held constant except wall thickness. Two mild steel specimens were tested having an internal radius of 3.84 inches and wall thicknesses of 0.4 inches for the first specimen and 0.3 inches for the second.

An exact theoretical solution of this problem involves mixed boundary conditions and the attendant complexities, and therefore, has not been solved. Prior to the construction of the 20-inch supersonic wind tunnel at the Jet Propulsion Laboratory, California Institute of Technology, it had been assumed generally that for piping which is to be stressed tangentially up to a value allowed by the governing code, the safe procedure would be to furnish heavy ribs to take all bending stresses of the elliptical intersection. Analysis of the loading induced in the joints of that wind tunnel, however, indicated that axial stiffness of the pipe itself would materially aid in resisting the deformation of the elliptical intersection. This prompted the series of tests reported in Reference (a). The results of these tests were not conclusive, and the investigator recommended that a more thorough study be made. No other study of this problem could be found in the engineering publications and indexes available at the California Institute of Technology.

The tests reported herein were made in collaboration with Lieutenant Commander Vernon E. Teig, U. S. Navy in the Structures

Laboratory, Guggenheim Aeronautical Laboratory, California Institute of Technology, Pasadena, California during the school year 1948-49.

EQUIPMENT AND PROCEDURE

The test specimens used in this investigation were made from two sections of eight-inch National Extra Strong Welded Steel Pipe, ASTM 53-47, having a yield point of 30,000 psi and an ultimate strength of 48,000 psi. These pipe sections were machined to the dimensions and uniformity shown in Figure 5. The axial dimension was made two and one half diameters to insure that the end effects would not interfere with the effects at the intersection. The sections were joined by welding so as to make ninety degree elbows. Any excess weld metal was ground down so as to approximate an integral specimen of constant wall thickness machined out of a single billet.

The pipe ends were sealed with standard eight-inch welding caps containing a three-quarters inch threaded stud located on the centerline having a nut provided for attaching a restraint between the ends of the specimen. The restraint was not used in these tests, however. The studs were drilled and tapped to receive hydraulic fittings. Except for wall thickness, which was 0.4 inch for specimen I and 0.3 inch for number II, the specimens were identical in all respects.

A large pan was placed under the specimens to receive the oil upon rupture and to prevent the pan walls from interfering with the hydraulic fittings connected to the pipes, the specimen was cradled in blocks at points about six and sixteen inches from the ends of the specimen.

Surface strains were measured with variable resistance wire strain gages of the Baldwin-Southwark AR-7 and A-8 types. The positions of

the active gages used in the tests are shown in Fig. 7.

Other equipment consisted of a potentiometer and Wheatstone's bridge circuit, a six-volt battery, a Blackhawk hand-operated hydraulic pump, hydraulic pressure gage and miscellaneous plumbing and electrical wiring.

The set upsof the test equipment are shown in Figures 1 and 3.

The procedure followed in each test was identical. Within the elastic limit of the specimens, strain gage readings were recorded with the specimens alternately loaded and unloaded, thereby providing average zero readings for each set of load readings and indicating yielding in the specimens when the gage readings failed to return to their preload values. Above the yield point of the specimens, strain gage readings were recorded as before with the specimen alternately loaded and unloaded, but only the zero reading obtained after loading was used in computing strains. In this region of plasticity, however, at intervals, before proceeding to a higher load, strain gage readings were recorded at intermediate loads. Readings at zero load were not taken after these intermediate loads but only after a load was applied which exceeded the highest previous load on the specimen. In order to obtain good results in the region of high strains, internal pressure was held constant, until strain readings stopped increasing, before data was recorded.

The amount of opening of the legs was measured during and after the application of each load. The measurement was made with a tram

bar between two punch marks made in the top of the studs located at the ends of the specimens. It was intended to report that portion of each test which was in the elastic range with the restraint applied across the legs to prevent bending. Since the amount of opening of the legs of each specimen was so small as to be unmeasurable in the elastic range, this portion of the intended investigation was abandoned.

RESULTS

The following results were obtained from the tests made on the two specimens described in EQUIPMENT AND PROCEDURE:

1. Stress and strain data recorded in Tables I to XVIII.
2. The loads resulting in yielding and rupture of the specimens were:

	Internal Pressure (psi)	
	Yield	Rupture
Specimen I	1800	3350
Specimen II	1200	2950

3. Rupture occurred across the weld at a point about 14.7 degrees above the crotch in both specimens.
4. The elliptical intersection was distorted into an egg shape with the broadest part of the egg on the crotch side of the elbow.
5. A visible area of cold-working was evident in the vicinity of the crotch of both specimens when high values of internal pressure were applied.

DISCUSSION

The data recorded during these tests were strain gage and battery voltage readings. In addition, the distance between two punch marks at the ends of the specimens (described in EQUIPMENT AND PROCEDURE) were measured. This distance did not change until immediately before rupture of the specimens.

The reduction of the strain gage readings taken within the elastic range into strains and stresses in the axial, tangential, and principal directions involved only the usual strain gage reduction equations and the classical elasticity equations for resolving stresses in a plane (see sample calculations). In the computation of stresses, a value of Young's Modulus of Elasticity equal to 30,000,000 psi and a value of Poisson's ratio of 0.3 were used.

In a uniform stress field, stresses and strains may be computed in the plasticity region from strain gage readings. This is possible because an elastic material strained beyond its elastic limit unloads and reloads along a curve parallel to the original curve of the material below the elastic limit. In a non-uniform stress field such as was present in the specimens tested, stresses can be computed only until the local yield point is reached. After any point in the specimen has yielded, all points in the specimen show strain when the applied load has been removed. For those points which have not reached their local yield point, these strains are due to residual stresses in the material set up by parts of the specimen which have taken on permanent set.

Utilizing this fact, the value of all stresses and strains can be computed from strain gage readings until the local yield point is reached. For the tests conducted, no stresses were computed after first yield of the specimens were reached since it is considered that they do not contribute to the analysis of the problem under investigation at this stage. After local yielding, the determination of stresses are impossible using elasticity equations since it is not known what part of the zero-load strain is due to permanent set and what part is due to residual stresses. Since the theory of plasticity is in a nebulous stage, computations in this range have been left for later study.

As an assistance in analyzing the stresses and strains measured and computed in this investigation, the graphs shown in Figs. 10 through 49 were prepared.

Strain gage readings taken above the elastic limit of a specimen previously have been considered in general to be unreliable. The similarity of strain curves for the two specimens at the various positions investigated, and at positions on the same specimen but removed from the critical intersection (i.e. curves 1, 2, and 4 of Fig. 12), indicate that strain gage readings taken above the elastic limit can be trusted in a qualitative analysis. Since the mechanical and electrical properties of the strain gages are not known to a high degree of certainty in this range, however, the readings obtained are of unknown reliability in a quantitative analysis.

Previous discussions of the intersection of circular cylinders under internal pressure have showed concern for the bending effects present. Results of this investigation do not indicate that the bending effects are of great relative importance. In tests of both specimens, no bending deformations were visible or measurable within the elastic range and were not of measurable magnitude in the plastic range until the load was increased to very nearly the rupture point. Furthermore, it is significant that the actual rupture of both specimens apparently was caused by tangential stresses despite the fact that specimen II had a tangential defect at the weld in the vicinity of the rupture point. This defect in specimen II was a small crack between the weld and the parent metal in the vicinity of the crotch. It opened visibly during the early stages of loading but eventual rupture was at right angles to this crack.

The classical equation for the tangential stress in a thick-walled cylinder under internal pressure is:

$$\sigma_t = \frac{pa^2}{r^2} \; \frac{r^2 + b^2}{b^2 - a^2}$$

which in the case of a pipe having the dimensions of specimen II is:

$$\sigma_t = 12.3188\ p$$

Thus, for the second specimen

$$p\ \text{yield} = \frac{30,000}{12.3188} = 2,435\ \text{psi}$$

$$p\ \text{ultimate} = \frac{48,000}{12.3188} = 3,978\ \text{psi}$$

The internal pressure causing yielding of specimen II was found experimentally to be 1200 psi, and of rupture to be 3350 psi.

In the case of specimen I:

p yield (straight tube - theoretical) = 3,288 psi

p yield (intersecting tubes - experimental) = 1,800 psi

p ultimate (straight tube - theoretical) = 5,261 psi

p ultimate (intersecting tubes - experimental) = 2,950 psi

The results of these tests, therefore, do not indicate "that welded pipe fittings can be designed with an ample safety factor against both excessive deformation and rupture, without the use of any ribbing and without increasing the thickness ratio of the fittings materially over that needed for plain pressure pipe", as was suggested in the conclusions of Reference (a.).

The deformation and point of rupture obtained with the "second specimen of 90 degree elbow made from seamless tubing, 4.5 inches O.D. with 0.12 inch wall thickness", reported in Reference (a), shows close agreement with the results obtained in this investigation. Since other tests on the 90-degree elbow reported in Reference (a) showed apparent structural defects in the pipe from which the specimens were made, it is considered that the results obtained therefrom (which did not agree with the results obtained in this investigation) are unreliable, and lead to false conclusions if considered.

Since yielding occurred at a load of approximately 54 per cent of the rupture pressure in the first specimen and at approximately 41 per cent of the rupture pressure in the second specimen, it is considered that limit design would be feasible in the construction of elbows similar to those tested where small permanent deformations could be tolerated. However, fatigue limitations to the theory of limit design must not be ignored.

The specimens used in this investigation were large and contained approximately eleven gallons of oil while tests were in progress. Large gravity effects were present, therefore, which may have had a considerable effect on stress distribution at low values of applied load. These gravity forces may cause highly undesirable bending effects when the specimen is supported by point reactions as was the case during these tests. These undesirable effects would be more in evidence in tests conducted on thinner-walled specimens, and it is recommended that for subsequent tests that a continuous support be provided.

Whereas experimental results obtained with the two specimens compared favorably in most respects, no explanation for the divergence of the axial strain curves of Figs. 29 and 30 can be offered. The divergence at these positions could be foreseen while data was being taken with the second specimen but no faulty techniques or instrumental failures were discovered. It is recommended that later phases of this investigation explore further the regions concerned.

CONCLUSIONS

The results of two tests are insufficient to indicate trends or establish facts as conclusive. The conclusions reached as a result of this investigation are, therefore, of such a nature as to require confirmation by subsequent continuation of this study. These conclusions are:

1. The maximum stresses present in specimens of the type tested are in the plane of the intersection and tangent to the ellipse of intersection at a point approximately fifteen degrees from the crotch. It is probable that when the legs of the specimen lie in the horizontal plane that the highest stress concentration is at an angle of approximately fifteen degrees <u>above</u> the crotch.

2. For two circular cylinders intersecting at right angles and acted on by internal pressure, the area in the vicinity of the intersection requires additional resistance to the high stresses present. For cylinders of about 8 inches internal diameter and 0.3 to 0.4 inches wall thickness, the wall thickness in the vicinity of the intersection should be increased approximately 100 per cent.

3. Bending associated with the stressing of two circular cylinders intersecting at right angles by the application of internal pressure appears to be of minor importance.

RECOMMENDATIONS

It is recommended that:

1. In any further experimental work conducted on this problem, that strain gage rosettes be located near the weld 15 degrees above and below the crotch.

2. In any further experimental work conducted on this problem, that a continuous support be provided on the under side of the specimens.

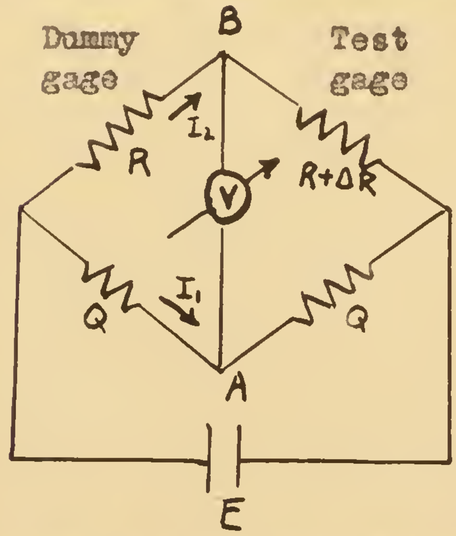
3. In any further work conducted on this problem that an investigation be made of the apparently incongruous results obtained in these tests for the axial strains near the weld at the rear of the intersection.

4. Further investigation be made of the bending present and of the effects of bending restraints.

EQUATIONS AND SAMPLE CALCULATIONS

A. REDUCTION OF STRAIN GAGE DATA

The test gage mounted on the specimen and a dummy gage mounted on identical, unstrained material are included in a Wheatstone Bridge



circuit. The opposite sides of the circuit are two precision resistances of magnitude Q.

Under load the potentiometer is varied so that no current flows between points A and B. We wish to determine the relation between the voltage V, across $\overline{AB}$ and the unit strain, ϵ, in the test specimen.

From the circuit diagram, we determine that

$$I_1(2Q) = E \qquad I_2 \quad (2R + \Delta R) = E \qquad V = I_1 Q - I_2 R$$

Hence

$$V = \frac{E}{2} - \frac{ER}{2R + \Delta R} = \frac{E}{4}\,\frac{\Delta R}{R}\left[1 + \frac{\Delta R}{2R}\right]^{-1} \approx \frac{E}{4}\,\frac{\Delta R}{R}$$

To eliminate the ratio $\Delta R/R$, the following relation for resistivity of a conductor is employed.

$$R = K\frac{L}{A}$$

where K is a resistivity constant, L the length of the conductor, and A its cross-sectional area. Then

$$\ln R = \ln K + \ln L - \ln A$$

Hence

$$\frac{\Delta R}{R} = \frac{\Delta L}{L} - \frac{\Delta A}{A}$$

For a cylindrical conductor

$$\frac{\Delta A}{A} = 2\,\frac{\Delta r}{r} = -2\nu\,\frac{L}{L} = -2\nu\epsilon$$

r is the radius of the cross section

Therefore

$$\frac{\Delta R}{R} = (1 + 2\nu)\,\epsilon$$

ν is the Poisson's ratio for the strain gage material.

Substituting directly into the equation for the voltage reading V,

$$V = \frac{E}{4}\,(1 + 2\nu)\,\epsilon$$

Hence

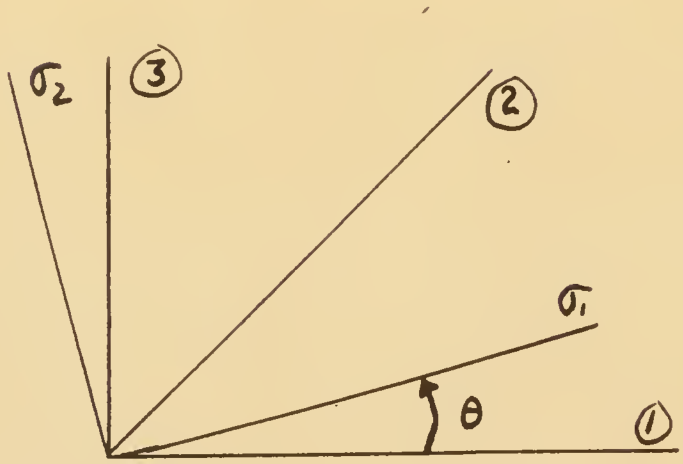
$$\epsilon = \frac{4V}{(1 + 2\nu)E}$$

This equation is usually employed in the form

$$\epsilon = \frac{4\ (\text{milli volts})}{(\text{gage factor})(\text{battery reading})}$$

where ϵ is obtained in inches per inch times 10^{-3}.

B. COMPUTATION OF STRAINS FROM STRAIN GAGE R'S (ROSETTES)



(a) $\Delta \epsilon_1 = R_1 - \frac{1}{k} R_3$

(b) $\Delta \epsilon_2 = 1.02\,\epsilon_2 - \frac{1}{k}(R_1 + R_3)$

(c) $\Delta \epsilon_3 = R_3 - \frac{1}{k} R_1$

where k = -200 for the rosettes used in these tests.

C. COMPUTATION OF AXIAL AND TANGENTIAL STRAINS

(a) $$\sigma_a = \frac{E}{1-\mu^2}\left[\epsilon_a + \mu(\epsilon_t)\right]$$

(b) $$\sigma_t = \frac{E}{1-\mu^2}\left[\epsilon_t + \mu(\epsilon_a)\right]$$

D. COMPUTATION OF PRINCIPAL STRESSES

$$\sigma_{1,2} = \frac{E}{2(1-\mu)(1+k)}\left[(R_1 + R_3) \pm \frac{(1-\mu)(1+k)}{(1+\mu)(1-k)} \cdot \gamma\right]$$

where

$$\gamma = \left| \frac{R_1 + R_3 + 2R_2}{\sin 2\theta} \right|$$

$$\tan 2\theta = -\frac{R_1 + R_3 - 2R_2}{R_1 - R_3}$$

E. COMPUTATION OF PRINCIPAL STRAIN

$$\epsilon_1 = \frac{1}{E}\left(\sigma_1 - \mu\,\sigma_2\right)$$

F. COMPUTATION OF STRAINS ABOVE ELASTIC LIMIT

Beyond the elastic limit, strains computed as above are but one component of the total strain. The other component is the strain remaining at a point with zero external load applied.

REFERENCES AND BIBLIOGRAPHY

a. Sandberg, William A.: "Tests of Welded Pipe Fittings", Progress Report No. 11-2. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, 6 October 1948.

b. Omsted, Harold and Serrurier, Mark: "Stress Analysis of Southern California Cooperative Wind Tunnel", CWT Report T-22, Southern California Cooperative Wind Tunnel, Pasadena, California (no date).

c. Sechler, E. E.: "Elasticity in Engineering", California Institute of Technology, Pasadena, California (classroom notes, 1949).

TABLE I

VARIATION OF TANGENTIAL AND AXIAL STRAINS WITH VARIATION OF INTERNAL PRESSURE

Test I | Position #1 | Gages 2,3

	R			$\Delta\epsilon$				σ			ϵ	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
500	.0430	.1133	-	.0436	.1135	-	-	-	2560	4170	.0436	.1135
750	.0645	.1416	-	.0652	.1419	-	-	-	3550	5320	.0652	.1419
1000	.0856	.1892	-	.0865	.1896	-	-	-	4725	7100	.0865	.1896
1250	.1068	.2381	-	.1080	.2386	-	-	-	5910	8930	.1080	.2386
1500	.1284	.2890	-	.1298	.2896	-	-	-	7140	10830	.1298	.2896
1600	.1325	.3003	-	.1340	.3010	-	-	-	7400	11240	.1340	.3010
1700	.1398	.3160	-	.1414	.3167	-	-	-	7800	11840	.1414	.3167
1800	.1468	.3335	-	.1485	.3342	-	-	-	-	-	.1460	.7388
1900	.1546	.3552	-	.1564	.3560	-	-	-	-	-	.1704	.7403
2000	.1627	.3856	-	.1646	.3864	-	-	-	-	-	.2075	.7209
2050	.1674	.3899	-	.1693	.3907	-	-	-	-	-	.2227	.7092
2150	.1809	.4807	-	.1833	.4816	-	-	-	-	-	.2449	.7873
750	.0616	.1480	-	.0623	.1483	-	-	-	-	-	.1239	.4540
1700	.1420	.3337	-	.1437	.3344	-	-	-	-	-	.2053	.6401
2200	.1850	.4263	-	.1871	.4356	-	-	-	-	-	.2581	.7481
2300	.1941	.4474	-	.1963	.4484	-	-	-	-	-	.2861	.7438
2400	.1993	.4922	-	.2018	.4932	-	-	-	-	-	.2938	.8333
2500	.2135	.4801	-	.2159	.4812	-	-	-	-	-	.2953	.9880
2600	.0804	.3915	-	.0824	.3955	-	-	-	-	-	.3602	2.2024
2800	.2096	.5993	-	.2126	.6003	-	-	-	-	-	.9139	4.1237
3000	.2146	.6726	-	.2161	.6937	-	-	-	-	-	1.1340	5.5106
3250	.2411	.7970	-	.2451	.7982	-	-	-	-	-	1.3111	6.8218

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE II

Test I — Position #2 — Gages 4,5,6

	R			Δ∈				σ			∈	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
500	.0181	.1318	.0696	.0188	.1319	.1322	2-42	4540	1889	4530	.0188	.1319
750	.0234	.1908	.1052	.0244	.1909	.1909	0-39	6534	2690	6540	.0244	.1909
1000	.0305	.2693	.1489	.0318	.2694	.2690	0-15	9189	3707	9177	.0318	.2694
1250	.0474	.3300	.1780	.0480	.3302	.3306	2-10	11382	4855	11340	.0480	.3302
1500	.0576	.4050	.2194	.0596	.4053	.4058	1-58	13964	5973	13920	.0596	.4053
1600	.0522	.4300	.2360	.0543	.4303	.4302	0-47	14722	6045	14690	.0543	.4303
1700	.0531	.4600	.2510	.0554	.4603	.4601	0-47	15719	6380	15700	.0554	.4603
1800	.0580	.4807	.2619	.0604	.4810	-	-	-	-	-	.0546	.4994
1900	.0657	.4976	.2736	.0682	.4979	-	-	-	-	-	.0512	.5335
2000	.0644	.5211	.2866	.0670	.5214	-	-	-	-	-	.0448	.6029
2050	.0690	.5319	.2935	.0717	.5322	-	-	-	-	-	.0379	.6365
2150	.0608	.5297	.2921	.0634	.5300	-	-	-	-	-	.0191	.8161
750	.0197	.2410	.1035	.0209	.2411	-	-	-	-	-	-.0234	.5272
1700	.0528	.4400	.2409	.0550	.4403	-	-	-	-	-	.0107	.7264
2200	.0693	.5643	.3106	.0721	.5646	-	-	-	-	-	.0302	.8649
2300	.0718	.4518	.2357	.0741	.4522	-	-	-	-	-	.0188	1.5388
2400	.0754	.5411	.2932	.0781	.5415	-	-	-	-	-	.0171	2.1654
2500	.0878	.5583	.3058	.0906	.5587	-	-	-	-	-	.0362	2.7001
2600	.0955	.6440	.3646	.0987	.6445	-	-	-	-	-	-.0780	3.8779
2800	.1176	.6682	.3796	.1209	.6688	-	-	-	-	-	-.2543	5.5926
3000	.1336	.8351	.4486	.1378	.8358	-	-	-	-	-	-.4013	7.8630
3250	.1358	.9513	.5011	.1406	.9520	-	-	-	-	-	-.4910	9.4319

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE III

Test I　　Position #3　　Gages 7.8.9

	R			ΔЄ				σ			ε	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
500	-0.0127	0.1562	0.0623	-0.0119	0.1561	.1566	86-59	5041	1151	5025	-0.0119	0.1561
750	-0.0167	0.2350	0.0910	-0.0155	0.2349	.2362	85-54	7621	1813	7595	- .0155	0.2349
1000	-0.0161	0.3273	0.1320	- .0145	0.3272	.3289	86-06	10684	2760	10650	- .0145	0.3272
1250	-0.0273	0.4080	0.1487	- .0253	0.4079	.4117	87-17	13286	3200	13200	- .0253	0.4079
1500	-0.0368	0.4970	θ.1875	-0.0343	0.4968	.5002	85-28	16118	3775	16050	- .0343	0.4968
1600	- .0397	0.5420	0.2098	-0.0370	0.5418	.5446	85-57	17561	4135	17500	- .0370	0.5418
1700	- .0487	0.5810	0.2221	-0.0458	0.5808	.5836	86-01	18760	4235	18700	- .0458	0.5808
1800	- .0421	0.6126	0.2367	- .0390	.6124	-	-	-	-	-	- .2812	1.2756
1900	- .0007	0.5102	.2010	+ .0019	.5102	-	-	-	-	-	- .4396	1.7756
2000	- .0641	0.7296	.2511	- .0605	.7293	-	-	-	-	-	- .7452	3.1196
2050	- .0600	0.6597	.2101	- .0567	.6594	-	-	-	-	-	- .7604	3.2577
2150	- .0648	0.7677	.2941	- .0610	.7674	-	-	-	-	-	-1.0346	5.3378
750	- .0176	0.2486	.1007	- .0164	.2484	-	-	-	-	-	- .9900	4.8188
1700	- .0552	0.6031	.2356	- .0522	.6028	-	-	-	-	-	-1.0258	5.1732
2200	- .0888	0.8357	.3172	- .0846	.8353	-	-	-	-	-	-1.0363	5.3448
2300	- .0333	0.9655	.3673	- .0285	.9653	-	-	-	-	-	-1.3724	8.2622
2400	- .0485	0.9982	.3958	- .0435	.9980	-	-	-	-	-	-1.8190	10.7686
2500	- .0661	1.0539	.4339	- .0608	1.0536	-	-	-	-	-	-2.2653	12.7903
2600	- .0889	1.1337	.4893	- .0832	1.1333	-	-	-	-	-	-2.9376	15.1911
2800	- .0841	NG	.5448	-	-	-	-	-	-	-	-	-
3000	- .1180	NG	.6350	-	-	-	-	-	-	-	-	-
3250	- .1311	NG	NG	-	-	-	-	-	-	-	-	-

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE IV

Test I | Position #4 | Gages 10,11,12

	R			ΔЄ				σ			Є	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
500	.0369	.1582	.1411	.0377	.1584	.1723	-17-51	5916	2805	5,590	.0377	.1584
750	.0565	.2183	.2070	.0576	.2186	.2443	-20-22	8369	4060	7,840	.0576	.2186
1000	.0748	.3270	.2862	.0764	.3274	.3533	-17-03	12148	5750	11,530	.0764	.3274
1250	.0996	.3977	.3467	.1016	.3982	.4274	-16-40	14808	7290	14,120	.1016	.3982
1500	.1150	.4890	.4240	.1174	.4896	.5257	-16-34	18136	8720	17,280	.1174	.4896
1600	.1502	.5220	.4620	.1528	.5228	.5611	-17-04	19632	10190	18,710	.1528	.5228
1700	0.1549	0.5520	0.4820	.1577	.5528	.5905	-16-28	20655	10650	19,780	.1577	.5528
1800	.1429	.5841	.5168	.1458	.5848	-	-	-	-	-	.1562	.5833
1900	.1595	.6040	.5370	.1625	.6048	-	-	-	-	-	.1532	.6169
2000	.1650	.6164	.5539	.1681	.6172	-	-	-	-	-	.1345	.7743
2050	.1738	.6133	.5646	.1769	.6142	-	-	-	-	-	.1422	.8531
2150	.1893	.6289	.5878	.1924	.6298	-	-	-	-	-	.1570	1.3555
750	.0650	.2287	.2057	.0661	.2290	-	-	-	-	-	.0302	0.9547
1700	.1481	.5132	.4655	.1507	.5139	-	-	-	-	-	.1148	1.2396
2200	.1944	.6584	.5990	.1977	.6554	-	-	-	-	-	.1725	1.3850
2300	.1821	.5772	.5305	.1850	.5781	-	-	-	-	-	.4297	2.0265
2400	.2165	.6072	.5714	.2195	.6083	-	-	-	-	-	.7248	2.7650
2500	.2469	.6392	.6210	.2501	.6322	-	-	-	-	-	.9061	3.3265
2600	.2667	.7040	.6368	.2702	.7053	-	-	-	-	-	1.0969	3.9296
2800	.2931	.7206	.6524	.2967	.7221	-	-	-	-	-	1.5359	5.2937
3000	.3268	.7730	.6833	.3307	.7746	-	-	-	-	-	2.1318	6.9961
3250	.3630	.8555	.6837	.3673	.8573	-	-	-	-	-	2.6431	8.6785

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE V

Test I | Position #5 | Gages 13,14,15

	R			$\Delta\epsilon$				σ			ϵ	
Press.	Axial	Along Weld	Normal to Weld	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
500	0.2150	0.1288	0.2170	0.2210	0.1293	.2344	66-45	8847	8474	6420	0.2210	.1293
750	0.3265	0.1955	0.3286	0.3356	0.1970	.3555	67-01	13415	12816	9758	.3356	.1970
1000	0.4380	0.2633	0.4440	.4503	0.2655	.4783	66-31	18070	17306	13158	.4503	.2655
1250	0.5324	0.3163	0.5420	.5473	.3190	.5834	66-16	21996	21076	15892	.5473	.3190
1500	0.6515	0.3854	0.6590	0.6698	.3887	.7120	66-43	26814	25634	19350	.6698	.3887
1600	0.7020	0.4150	0.7140	0.7216	.4185	.7694	66-19	28979	27748	20880	.7216	.4185
1700	0.7370	0.4330	0.7580	0.7576	.4343	.8128	65-32	30596	29381	21917	.7576	.4343
1800	0.7797	0.4558	0.7959	.8016	.4599	-	-	-	-	-	.8933	.4476
1900	0.8272	0.4849	0.8498	.8504	.4892	-	-	-	-	-	1.1027	.4711
2000	0.8738	0.5068	0.8907	.8983	.5115	-	-	-	-	-	1.3280	.4510
2050	0.8844	0.5203	0.9001	.9092	.5249	-	-	-	-	-	1.4455	.4866
2150	0.9243	0.5438	0.9376	.9502	.5486	-	-	-	-	-	1.8839	.6597
750	0.3123	0.1795	0.3096	.3209	.1811	-	-	-	-	-	1.2546	.2922
1700	0.7164	0.4150	0.7269	.7364	.4187	-	-	-	-	-	1.6701	.5298
2200	0.9250	0.5356	0.9381	.9509	.5404	-	-	-	-	-	1.9229	.6762
2300	0.9648	0.5649	1.0095	.9920	.5700	-	-	-	-	-	2.9586	1.1058
2400	1.0026	0.5841	1.0292	1.0307	.5615	-	-	-	-	-	3.6251	1.3387
2500	1.0108	0.5920	1.0229	1.0391	.7058	-	-	-	-	-	4.2130	1.7047
2600	1.0683	0.6175	1.0510	1.0980	.6229	-	-	-	-	-	5.0013	1.8820
2800	1.0585	0.6775	1.0585	1.0884	.6829	-	-	-	-	-	6.8464	2.4601
3000	1.0871	0.7703	1.0629	1.1180	.7770	-	-	-	-	-	8.9184	2.9686
3250	1.1626	0.9040	1.0636	1.1956	.9095	-	-	-	-	-	10.7605	3.5506

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE VI

Test I — Position #6 — Gages 16,17,18

	R			ΔE				σ			ε	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
500	-.0101	.2050	.0429	-.0091	.2045	.2180	13-28	6970	1725	6650	-.0091	.2045
750	-.0127	.3055	.0408	-.0112	.3054	.3371	16-47	10691	2650	9950	-.0112	.3054
1000	-.0141	0.4170	0.0554	-.0120	.4169	.4615	17-04	14655	3730	13640	-.0120	.4169
1250	-.0126	0.5090	0.0717	-.0101	.5089	.5627	17-03	17920	4700	16690	-.0101	.5089
1500	-.0126	.6235	.0873	-.0095	.6234	.6907	17-14	22012	5850	20470	-.0095	.6234
1600	-.0093	0.6720	0.0959	-.0059	.6720	.7450	17-20	23780	6450	22100	-.0059	.6720
1700	-.0162	0.7100	0.0987	-.0126	.7099	.7862	17-11	25042	6610	23270	-.0126	.7099
1800	-.0126	0.7495	0.1074	-.0089	.7494	-	-	-	-	-	.0332	.6988
1900	-.0073	0.8001	0.1144	-.0033	.8001	-	-	-	-	-	.0883	.8339
2000	.0056	0.8535	0.1308	.0099	.8535	-	-	-	-	-	.2527	1.0209
2050	.0053	0.8551	0.1434	.0096	.8551	-	-	-	-	-	.2884	.8756
2150	.0260	0.9246	0.1562	.0306	.9247	-	-	-	-	-	.6063	1.8557
750	.0063	.2957	.0547	.0078	.2957	-	-	-	-	-	.5835	1.2267
1700	.0253	.8017	.1281	.0293	.8018	-	-	-	-	-	.6050	1.7328
2200	.0395	.9467	.1609	.0442	.9469	-	-	-	-	-	.5930	1.9099
2300	.0632	1.0085	.1958	.0682	1.0088	-	-	-	-	-	1.3146	3.8451
2400	.1191	1.1052	.2224	.1246	1.1058	-	-	-	-	-	1.8874	5.2142
2500	.1674	1.1740	.2418	.1733	1.1748	-	-	-	-	-	2.2353	6.2563
2600	.2271	1.2371	.2678	.2333	1.2382	-	-	-	-	-	2.5718	7.4738
2800	.3148	1.3137	.3051	.3214	1.3153	-	-	-	-	-	2.9714	9.8491
3000	.3834	1.3148	.3416	.3900	1.3167	-	-	-	-	-	2.7935	12.0549
3250	.3106	NO	.3779	.3106	-	-	-	-	-	-	-	-

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE VII

Test I **Position #7** **Gages 19.20.21**

	R			ΔЄ					σ		ε	
Press.	**Axial**	**Along Weld**	**Normal to Weld**	**Axial**	**Tang.**	**Princ.**	**θ**	**Princ.**	**Axial**	**Tang.**	**Axial**	**Tang.**
500	.0700	-.0385	.0868	.0716	-.0381	.1015	-63-06	2823	2479	-399	.0716	-.0381
750	.1045	-.0615	.1253	.1069	-.0608	.1451	-63-55	4090	3518	-770	.1069	-.0608
1000	.1340	-.0818	.1759	.1372	-.0809	.2019	-62-06	5594	4983	-931	.1372	-.0809
1250	.1732	-.1040	.2082	.1772	-.1029	.2488	-64-00	6779	5827	-1339	.1772	-.1029
1500	.2276	-.1344	.2633	.2328	-.1386	.3206	-64-42	8681	7469	-1917	.2328	-.1386
1600	.2382	-.1400	.2780	.2437	-.1442	.3368	-64-30	9144	7901	-1957	.2437	-.1442
1700	.2477	-.1452	.2900	.2534	-.1438	.3508	-64-30	9534	8113	-1881	.2534	-.1438
1800	.2549	-.1508	.3186	.2608	-.1492	-	-	-	-	-	.3051	-.1899
1900	.2690	-.1542	.3344	.2753	-.1525	-	-	-	-	-	.3469	-.2175
2000	.2753	-.1650	.3544	.2817	-.1633	-	-	-	-	-	.4062	-.3066
2050	.2941	-.1581	.3635	.3010	-.1500	-	-	-	-	-	.4235	-.3159
2150	.3064	-.1632	.3728	.3135	-.1614	-	-	-	-	-	.4603	-.4078
750	.1011	-.0599	.1220	.1034	-.0623	-	-	-	-	-	.2502	-.3087
1700	.2411	-.0599	.2942	.2471	-.0584	-	-	-	-	-	.3939	-.3048
2200	.3175	-.1641	.3826	.3249	-.1622	-	-	-	-	-	.4706	-.4109
2300	.3123	-.1560	.3890	.3197	-.1520	-	-	-	-	-	.4601	-.5308
2400	.3228	-.1614	.4048	.3304	-.1595	-	-	-	-	-	.4598	-.6319
2500	.3268	-.1598	.4109	.3346	-.1578	-	-	-	-	-	.4973	-.7219
2600	.3380	-.1544	.4311	.3462	-.1523	-	-	-	-	-	.5333	-.8354
2800	.3486	-.1458	.4686	.3572	-.1435	-	-	-	-	-	.6613	-1.0814
3000	.3630	-.1373	.5138	.3722	-.1344	-	-	-	-	-	.7355	-1.3375
3250	.4287	-.1021	.5800	.4397	-.0991	-	-	-	-	-	.8197	-1.4149

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE VIII

Test I | Position #8 | Gages 22&23

Press.	R Axial	R Tang.	R Diag.	ΔΕ Axial	ΔΕ Tang.	ΔΕ Princ.	θ	σ Princ.	σ Axial	σ Tang.	ε Axial	ε Tang.
500	.0058	-.0613	-	.0058	-.0613	.0058	0	-415	-415	-1965	.0058	-.0613
750	.0054	-.0875	-	.0054	-.0875	.0054	0	-686	-686	-2832	.0054	-.0875
1100	.0018	-.1263	-	.0018	-.1263	.0018	0	-1190	-1190	-4148	.0018	-.1263
1250	.0118	-.1675	-	.0118	-.1675	.0118	0	-1266	-1266	-5407	.0118	-.1675
1500	.0218	-.1956	-	.0218	-.1956	.0218	0	-1216	-1216	-6235	.0218	-.1956
1600	.0352	-.2100	-	.0352	-.2100	.0352	0	-916	-916	-6574	.0352	-.2100
1700	.0419	-.2280	-	.0419	-.2280	.0419	0	-874	-874	-7102	.0419	-.2280
1800	.0417	-.2425	-	.0417	-.2425	-	-	-	-	-	.1019	-.2680
1900	.0474	-.2563	-	.0474	-.2563	-	-	-	-	-	.1469	-.2941
2000	.0597	-.2696	-	.0597	-.2696	-	-	-	-	-	.2184	-.3303
2050	.0640	-.2696	-	.0640	-.2696	-	-	-	-	-	.2329	-.3382
2150	.0720	-.2891	-	.0720	-.2891	-	-	-	-	-	.3098	-.3850
750	-.0003	-.0825	-	-.0003	-.0325	-	-	-	-	-	.2375	-.1784
1700	.0283	-.2000	-	.0283	-.2000	-	-	-	-	-	.2661	-.2959
2200	.0646	-.2606	-	.0646	-.2606	-	-	-	-	-	.3148	-.3556
2300	.0789	-.2942	-	.0789	-.2942	-	-	-	-	-	.4184	-.4651
2400	.0903	-.3029	-	.0903	-.3092	-	-	-	-	-	.5437	-.6020
2500	.1060	-.3259	-	.1060	-.3259	-	-	-	-	-	.7146	-.8523
2600	.1161	-.3248	-	.1161	-.3248	-	-	-	-	-	.7247	-.8512
2800	.1401	-.3318	-	.1401	-.3318	-	-	-	-	-	.9385	-1.2150
3000	.1855	-.3549	-	.1855	-.3549	-	-	-	-	-	1.1440	-1.7719
3250	.2273	-.3218	-	.2273	-.3218	-	-	-	-	-	1.2880	-2.0626

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE IX

Test I — Position #9 — Gages 1-24

	R			$\Delta\epsilon$				σ			ϵ	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
500	0.0468	0.2245	-	0.0468	0.2245	0.2245	090	7860	3762	7860	.0468	.2245
750	0.0646	0.3290	-	0.0646	0.3290	0.3290	090	11500	5385	11500	.0646	.3290
1000	0.0585	0.4560	-	0.0585	0.4560	0.4560	090	15600	6440	15600	.0585	.4560
1250	0.1178	0.5720	-	0.1178	0.5720	0.5720	090	20000	9535	20000	.1178	.5720
1500	0.1340	0.6980	-	0.1340	0.6980	0.6980	090	24300	11320	24300	.1340	.6980
1600	0.1235	0.7580	-	0.1235	0.7580	0.7580	090	26200	11560	26200	.1235	.7580
1700	0.1310	0.8120	-	0.1310	0.8120	0.8120	090	28050	12350	28050	.1310	.8120
1800	0.1441	0.8602	-	.1441	0.8602	-	-	-	-	-	.1246	1.0058
1900	0.1366	0.9786	-	.1366	0.9786	-	-	-	-	-	.1843	2.0139
2000	0.1198	1.0962	-	.1198	1.0962	-	-	-	-	-	.2643	3.7938
2050	0.1084	1.1037	-	.1084	1.1037	-	-	-	-	-	.3632	4.1425
2150	0.1140	1.1809	-	.1140	1.1809	-	-	-	-	-	.5995	6.6369
750	0.0346	.3310	-	.0346	.3310	-	-	-	-	-	.5201	5.7870
1700	.0958	.8170	-	.0958	.8170	-	-	-	-	-	.5813	6.2730
2200	.1198	1.0619	-	.1198	1.0619	-	-	-	-	-	.5911	6.3979
2300	.0827	NG	-	.0827	-	-	-	-	-	-	.9537	-
2400	.1373	NG	-	.1373	-	-	-	-	-	-	1.1481	-
2500	.1609	NG	-	.1609	-	-	-	-	-	-	1.1530	-
2600	.1669	NG	-	.1669	-	-	-	-	-	-	1.0149	-
2800	.1644	NG	-	.1644	-	-	-	-	-	-	.4478	-
3000	.1006	NG	-	.1006	-	-	-	-	-	-	-.2094	-
3250	.0175	NG	-	.0175	-	-	-	-	-	-	-.6431	-

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE NO.X

VARIATION OF TANGENTIAL AND AXIAL STRAINS WITH VARIATION OF INTERNAL PRESSURE

Test II | Position #1 | Gages 2,3

	R			$\Delta\epsilon$				σ			ϵ	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
400	.0600	.1385	-	.0670	.1388	-	-	-	3580	5239	.0670	.1388
600	.0815	.1970	-	.0825	.1974	-	-	-	4672	7326	.0825	.1974
800	.1142	.2680	-	.1155	.2686	-	-	-	6465	9996	.1155	.2686
1000	.1376	.3298	-	.1392	.3305	-	-	-	7860	12275	.1392	.3305
1100	.1535	.3677	-	.1553	.3685	-	-	-	8767	13686	.1553	.3685
1200	.1657	.4020	-	.1677	.4028	-	-	-	-	-	.1795	.3831
1250	.1724	.4182	-	.1745	.4191	-	-	-	-	-	.1905	.3906
1300	.1848	.4316	-	.1870	.4325	-	-	-	-	-	.2070	.3978
500	.0705	.1632	-	.0713	.1636	-	-	-	-	-	.0913	.1289
900	.1254	.3019	-	.1269	.3025	-	-	-	-	-	.1469	.2678
1400	.1940	.4794	-	.1964	.4804	-	-	-	-	-	.2531	.3806
1600	.2226	.5814	-	.2255	.5825	-	-	-	-	-	.3474	.3389
600	.0869	.2171	-	.0880	.2175	-	-	-	-	-	.2099	-.0261
1200	.1718	.4421	-	.1740	.4430	-	-	-	-	-	.2959	.1994
1800	.1989	.6038	-	.2019	.6048	-	-	-	-	-	.6174	1.7911
2000	.2622	.8185	-	.2663	.8198	-	-	-	-	-	1.1349	4.1168
2200	.2623	.9078	-	.2668	.9091	-	-	-	-	-	1.4475	6.6002
2400	.2727	1.0532	-	.2780	1.0546	-	-	-	-	-	1.7004	9.4359
2600	.2848	1.1135	-	.2904	1.1149	-	-	-	-	-	1.8471	12.5249
2800	.2852	NG	-	-	-	-	-	-	-	-	-	-

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE XI

Test II — Position #2 — Gages 4,5,6

	R			$\Delta\epsilon$				σ			ϵ	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
400	.0112	.1296	.0739	.0118	.1297	.1296	-1-28	4401	1672	4392	.0118	.1297
600	.0172	.1824	.1164	.0181	.1825	.1841	-5-41	6234	2404	6195	.0181	.1825
800	.0228	.2475	.1564	.0240	.2476	.2497	-5-21	8450	3241	8401	.0240	.2476
1000	.0284	.3047	.1918	.0299	.3048	.3070	-5-11	10397	3999	10346	.0299	.3048
1100	.0307	.3374	.2152	.0324	.3376	.3408	-5-45	11524	4408	11450	.0324	.3376
1200	.0358	.3708	.2357	.0377	.3710	-	-	-	-	-	.0247	.3668
1250	.0375	.3804	.2408	.0394	.3806	-	-	-	-	-	.0246	.3797
1300	.0375	.3944	.2456	.0395	.3946	-	-	-	-	-	.0216	.3968
500	.0140	.1506	.0941	.0148	.1507	-	-	-	-	-	-.0031	.1529
900	.0253	.2773	.1742	.0267	.2774	-	-	-	-	-	.0088	.2796
1400	.0392	.4182	.2618	.0413	.4184	-	-	-	-	-	.0087	.4508
1600	.0443	.4806	.3925	.0467	.4808	-	-	-	-	-	-.0148	.6006
600	.0166	.1751	.1109	.0175	.1752	-	-	-	-	-	-.0440	.2950
1200	.0296	.3525	.2184	.0314	.3526	-	-	-	-	-	-.0301	.4724
1800	.0653	.5121	.3289	.0679	.5124	-	-	-	-	-	-.0584	.7023
2000	.0794	.6330	.4089	.0826	.6334	-	-	-	-	-	-.2413	4.3461
2200	.1129	.7303	.4958	.1166	.7309	-	-	-	-	-	-.5001	6.8078
2400	.1365	.8720	.5836	.1409	.8727	-	-	-	-	-	-.6110	9.2633
2600	.1419	.9022	.6138	.1464	.9029	-	-	-	-	-	-.6156	11.1987
2800	.1772	.9618	.6995	.1820	.9627	-	-	-	-	-	-.5345	12.4117

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE XII

Test II Position #3 Gages 7.8.9

Press.	R Axial	R Tang.	R Diag.	$\Delta\epsilon$ Axial	$\Delta\epsilon$ Tang.	$\Delta\epsilon$ Princ.	θ	σ Princ.	σ Axial	σ Tang.	ϵ Axial	ϵ Tang.
400	-.0145	.1962	.0762	-.0135	.1961	.1972	+86-02	6356	1491	6334	-.0135	.1961
600	-.0211	.2798	.1095	-.0197	.2797	.2811	+86-14	9058	2117	9027	-.0197	.2797
800	-.0284	.3848	.1515	-.0265	.3847	.3863	+86-19	12459	2931	12420	-.0265	.3847
1000	-.0386	.4796	.1862	-.0362	.4794	.4819	+86-13	15504	3548	15446	-.0362	.4794
1100	-.0446	.5384	.2080	-.0419	.5382	.5410	+86-12	17394	3943	17329	-.0419	.5382
1200	-.0475	.6036	.2287	-.0445	.6034	-	-	-	-	-	-.1597	.8508
1250	-.0545	.6186	.2355	-.0514	.6183	-	-	-	-	-	-.2109	1.0195
1300	-.0588	.6543	.2466	-.0555	.6540	-	-	-	-	-	-.3137	1.3860
500	-.0186	.2354	.0948	-.0174	.2353	-	-	-	-	-	-.2756	.9673
900	-.0386	.4492	.1706	-.0364	.4490	-	-	-	-	-	-.2946	1.1810
1400	-.0652	.7153	.2831	-.0616	.7150	-	-	-	-	-	-.8225	3.1558
1600	-.1002	.9984	.3850	-.0952	.9979	-	-	-	-	-	-2.0917	8.4310
600	-.0303	.3196	.1352	-.0287	.3194	-	-	-	-	-	-2.0252	7.7525
1200	-.0583	.6458	.2583	-.0551	.6455	-	-	-	-	-	-2.0516	8.0786
1800	-.1563	NG	.4931	-	-	-	-	-	-	-	-	-
2000	-.1540	NG	.3516	-	-	-	-	-	-	-	-	-
2200	-.1809	NG	.7002	-	- -	-	-	-	-	-	-	-
2400	-.2214	NG	.8117	-	-	-	-	-	-	-	-	-
2600	-.1979	NG	NG	-	-	-	-	-	-	-	-	-
2800	-.0874	NG	NG	-	-	-	-	-	-	-	-	-

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE XIII

Test II | Position #4 | Gages 10,11,12

Press.	R Axial	R Tang.	R Diag.	Δϵ Axial	Δϵ Tang.	Δϵ Princ.	θ	σ Princ.	σ Axial	σ Tang.	ϵ Axial	ϵ Tang.
400	.0366	.1817	.1698	.0375	.1819	.2038	-19-57	6873	3036	6366	.0375	.1819
600	.0567	.2586	.2441	.0580	.2589	.2907	-20-18	9844	4474	9110	.0580	.2589
800	.0729	.3511	.3267	.0747	.3515	.3925	-19-46	13273	5938	12327	.0747	.3515
1000	.0924	.4308	.4087	.0946	.4313	.4860	-20-30	16418	7385	15156	.0946	.4313
1100	.1023	.4780	.4473	.1047	.4785	.5354	-19-58	18124	8186	16811	.1047	.4785
1200	.1162	.5226	.4847	.1188	.5232	-	-	-	-	-	.1022	.5148
1250	.1212	.5345	.4993	.1239	.5351	-	-	-	-	-	.1017	.5217
1300	.1259	.5470	.5117	.1286	.5476	-	-	-	-	-	.0998	.5286
500	.0462	.2125	.1975	.0473	.2127	-	-	-	-	-	.0185	.1937
900	.0864	.3890	.3411	.0883	.3894	-	-	-	-	-	.0595	.3704
1400	.1404	.5819	.5403	.1433	.5826	-	-	-	-	-	.0795	.5115
1600	.1927	.6107	.5701	.1958	.6117	-	-	-	-	-	-.0536	.5417
600	.0649	.2404	.2171	.0661	.2407	-	-	-	-	-	-.1833	.1707
1200	.1375	.4740	.4328	.1399	.4747	-	-	-	-	-	-.1095	.4047
1800	.2279	.6714	.5814	.2313	.6725	-	-	-	-	-	.6633	2.4305
2000	.3182	.7103	.5727	.3218	.7119	-	-	-	-	-	1.6984	4.8164
2200	.3792	.8006	.5930	.3832	.8025	-	-	-	-	-	2.5154	7.0360
2400	.4330	.9358	.6742	.4377	.9380	-	-	-	-	-	3.5395	9.9191
2600	.4897	1.0230	.6909	.4958	1.0254	-	-	-	-	-	4.8255	13.2397
2800	.5078	1.0089	.7735	.5128	1.0114	-	-	-	-	-	6.9492	18.8651

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE XIV

Test II

Position #5

Gages 13,14,15

	R			$\Delta\epsilon$				σ			ϵ	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
400	.2625	.1332	.2447	.2632	.1345	.2783	+72-02	10356	10010	7039	.2632	.1345
600	.3728	.1923	.3520	.3738	.1942	.3841	+71-32	14481	14246	10099	.3738	.1942
800	.5032	.2584	.4749	.5045	.2609	.5364	+71-13	19950	19215	13594	.5045	.2609
1000	.6292	.3195	.5919	.6308	.3226	.6625	+71-24	24900	23989	16874	.6308	.3226
1100	.6909	.3459	.6490	.6926	.3494	.7364	+71-26	27302	26290	18371	.6926	.3494
1200	.7570	.3778	.7105	.7589	.3816	-	-	-	-	-	.9014	.3298
1250	.7700	.3827	.7258	.7719	.3866	-	-	-	-	-	.9568	.3201
1300	.7945	.3898	.7434	.7964	.3938	-	-	-	-	-	1.0488	.3248
500	.3039	.1523	.2876	.3047	.1538	-	-	-	-	-	.5571	.0848
900	.5576	.2826	.5277	.5590	.2854	-	-	-	-	-	.8114	.2164
1400	.8687	.4258	.8154	.8708	.4301	-	-	-	-	-	1.4479	.3315
1600	.9385	.4719	.8862	.9409	.4766	-	-	-	-	-	3.0029	.5085
600	.3329	.1861	.3163	.3338	.1878	-	-	-	-	-	2.3958	.2197
1200	.6525	.3559	.6259	.6543	.3592	-	-	-	-	-	2.7163	.3911
1800	.9330	.5298	.8630	.9356	.5345	-	-	-	-	-	4.7072	.8899
2000	.9076	.5814	.8339	.9105	.5859	-	-	-	-	-	6.2507	1.0764
2200	.9146	.7028	.8174	.9181	.7074	-	-	-	-	-	8.7857	1.6676
2400	.9861	.8362	.8385	.9903	.8411	-	-	-	-	-	11.6937	2.8194
2600	1.0498	.9176	.9190	1.0544	.9228	-	-	-	-	-	14.6300	4.8068
2800	NG	.9635	.9618	-	-	-	-	-	-	-	-	-

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE XV

Test II — Position #6 — Gages 16,17,18

	R			Δε				σ			ε	
Press.	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
400	-.0112	.2513	.0228	-.0099	.2512	.2833	+18-16	8924	2160	8183	-.0099	.2512
600	-.0327	.3616	.0356	-.0309	.3614	.3997	+16-35	12493	2555	11609	-.0309	.3614
800	-.0234	.4904	.0492	-.0209	.4903	.5494	+17-50	17320	4161	15957	-.0209	.4903
1000	-.0271	.6189	.0588	-.0240	.6188	.6962	+18-09	21949	5328	20164	-.0240	.6188
1100	-.0267	.6813	.0670	-.0233	.6812	.7663	+18-10	24192	5971	22228	-.0233	.6812
1200	-.0239	.7516	.0764	-.0201	.7515	-	-	-	-	-	.0675	.9130
1250	-.0236	.7700	.0807	-.0198	.7699	-	-	-	-	-	.1160	.9642
1300	-.0156	.8065	.0871	-.0116	.8064	-	-	-	- -	-	.1944	1.0455
500	-.0123	.3002	.0269	-.0108	.3001	-	-	-	-	-	.1952	.5392
900	-.0200	.5619	.0592	-.0172	.5618	-	-	-	-	-	.1888	.8009
1400	.0063	.9046	.1094	.0108	.9046	-	-	-	-	-	.5171	1.5374
1600	.0998	1.1515	.1934	.1056	1.1520	-	-	-	-	-	2.1334	5.4698
600	.0223	0.3995	.0636	.0243	.3996	-	-	-	-	-	2.0521	4.7174
1200	.0383	0.7923	.1262	.0423	.7925	-	-	-	-	-	2.0701	5.1103
1800	.1779	1.3328	.2289	.1846	1.3337	-	-	-	-	-	2.6365	10.6465
2000	.2632	1.4870	.2820	.2706	1.4883	-	-	-	-	-	2.9129	16.1530
2200	.3718	NG	.3126	-	-	-	-	-	-	-	-	-
2400	.4696	NG	.3324	-	-	-	-	-	-	-	-	-
2600	.5635	NG	.2928	-	-	-	-	-	-	-	-	-
2800	.6793	NG	.1957	-	-	-	-	-	-	-	-	-

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE XVI

Test II — Position #7 — Gages 19,20,21

Press.	R Axial	R Tang.	R Diag.	Δε Axial	Δε Tang.	Δε Princ.	θ	σ Princ.	σ Axial	σ Tang.	ε Axial	ε Tang.
400	-.0066	-.0336	.0425	-.0068	-.0336	.0435	+38-55	- 605	-557	-1174	-.0068	-.0336
600	-.0112	-.0475	.0614	-.0114	-.0476	.0626	+39-21	- 862	-847	-1681	-.0114	-.0476
800	-.0175	-.0640	.0822	-.0178	-.0641	.0836	+39-29	-1118	-1220	-2288	-.0178	-.0641
1000	-.0224	-.0759	.1013	-.0228	-.0760	.1026	+39-58	-1391	-1503	-2730	-.0228	-.0760
1100	-.0244	-.0838	.1132	-.0248	-.0839	.1147	+39-58	-1570	-1648	-3010	-.0248	-.0839
1200	-.0242	-.0896	.1218	-.0246	-.0897	-	-	-	-	-	-.0298	-.1084
1250	-.0269	-.0860	.1236	-.0273	-.0861	-	-	-	-	-	-.0318	-.1169
1300	-.0276	-.0930	.1269	-.0281	-.0931	-	-	-	-	-	-.0316	-.1277
500	-.0103	-.0359	.0499	-.0105	-.0360	-	-	-	-	-	-.0140	-.0706
900	-.0203	-.0678	.0938	-.0206	-.0679	-	-	-	-	-	-.0241	-.1025
1400	-.0333	-.1031	.1334	-.0338	-.1033	-	-	-	-	-	-.0387	-.1686
1600	-.0493	-.0998	.1394	-.0498	-.1000	-	-	-	-	-	-.0634	-.2847
600	-.0156	-.0389	.0509	-.0158	-.0390	-	-	-	-	-	-.0294	-.2237
1200	-.0413	-.0802	.1015	-.0417	-.0804	-	-	-	-	-	-.0553	-.2651
1800	-.0743	-.1020	.1379	-.0748	-.1024	-	-	-	-	-	-.2306	-.4977
2000	-.1085	-.0854	.1229	-.1089	-.0859	-	-	-	-	-	-.4937	-.7576
2200	-.1139	-.0573	.1440	-.1142	-.0579	-	-	-	-	-	-.8624	-.9176
2400	-.1261	-.0255	.1821	-.1262	-.0261	-	-	-	-	-	-1.0256	-.8471
2600	-.1211	.0154	.2083	-.1210	.0148	-	-	-	-	-	-1.1384	-.6243
2800	-.0847	.0710	.2546	-.0843	.0706	-	-	-	-	-	-1.5323	-.1973

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE XVII

Test II | Position #8 | Gages 22 & 23

Press.	ΔR Axial	ΔR Tang.	ΔR Diag.	$\Delta\epsilon$ Axial	$\Delta\epsilon$ Tang.	$\Delta\epsilon$ Princ.	θ	σ Princ.	σ Axial	σ Tang.	ϵ Axial	ϵ Tang.
400	-.0390	-.0307	-	-.0390	-.0307	-.0307	-	-	-1589	-1398	-.0390	-.0307
600	-.0579	-.0432	-	-.0579	-.0432	-.0432	-	-	-2338	-1998	-.0579	-.0432
800	-.0730	-.0597	-	-.0730	-.0597	-.0597	-	-	-2977	-2690	-.0730	-.0597
1100	-.0934	-.0741	-	-.0934	-.0741	-.0741	-	-	-3811	-3366	-.0934	-.0741
1100	-.1023	-.0801	-	-.1023	-.0801	-.0801	-	-	-4164	-3653	-.1023	-.0801
1200	-.1083	-.0856	-	-.1083	-.0856	-	-	-	-	-	-.1270	-.0846
1250	-.1145	-.0896	-	-.1145	-.0896	-	-	-	-	-	-.1355	-.0848
1300	-.1171	-.0918	-	-.1171	-.0918	-	-	-	-	-	-.1370	-.0833
500	-.0443	-.0353	-	-.0443	-.0353	-	-	-	-	-	-.0642	-.0268
900	-.0868	-.0674	-	-.0868	-.0674	-	-	-	-	-	-.1067	-.0588
1400	-.1255	-.0963	-	-.1255	-.0963	-	-	-	-	-	-.1465	-.0732
1600	-.1479	-.0923	-	-.1479	-.0923	-	-	-	-	-	-.2295	-.0248
600	-.0635	-.0361	-	-.0635	-.0361	-	-	-	-	-	-.1451	.0314
1200	-.1248	-.0754	-	-.1248	-.0754	-	-	-	-	-	-.2064	-.0079
1800	-.1697	-.0787	-	-.1697	-.0787	-	-	-	-	-	-.3453	.3800
2000	-.1945	-.0733	-	-.1945	-.0733	-	-	-	-	-	-.4368	-.0032
2200	-.1808	-.0610	-	-.1808	-.0610	-	-	-	-	-	-.6109	.0402
2400	-.1527	-.0502	-	-.1527	-.0502	-	-	-	-	-	-.7606	.1302
2600	-.1447	-.0276	-	-.1447	-.0276	-	-	-	-	-	-.9359	.2580
2800	-.1137	-.0113	-	-.1137	-.0113	-	-	-	-	-	-1.2371	.5097

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^3

TABLE XVIII

Test II Position #9 Gages 1 & 24

Press.	R			$\Delta\epsilon$				σ			ϵ	
	Axial	Tang.	Diag.	Axial	Tang.	Princ.	θ	Princ.	Axial	Tang.	Axial	Tang.
400	.0379	.2609	-	.0379	.2609	.2609	-	-	3831	8978	.0379	.2609
600	.0586	.3790	-	.0586	.3790	.3790	-	-	5681	13076	.0586	.3790
800	.0790	.5128	-	.0790	.5128	.5128	-	-	7675	17688	.0790	.5128
1000	.1023	.6519	-	.1023	.6519	.6519	-	-	9822	22505	.1023	.6519
1100	.1174	.7238	-	.1174	.7238	.7238	-	-	11028	25024	.1174	.7238
1200	.0953	.8185	-	.0953	.8185	-	-	-	-	-	.2061	1.1963
1250	.0911	.8575	-	.0911	.8575	-	-	-	-	-	.2821	1.4422
1300	.0774	.9016	-	.0774	.9016	-	-	-	-	-	.4146	1.8942
500	.0483	.3181	-	.0483	.3181	-	-	-	-	-	.3855	1.3107
900	.0890	.6071	-	.0890	.6071	-	-	-	-	-	.4262	1.5997
1400	.1186	1.0540	-	.1186	1.0540	-	-	-	-	-	.8126	4.1393
1600	.1198	NG	-	.1198	-	-	-	-	-	-	1.3072	-
600	.0375	NG	-	.0375	-	-	-	-	-	-	1.2249	-
1200	.0563	NG	-	.0563	-	-	-	-	-	-	1.2437	-
1300	.1484	NG	-	.1484	-	-	-	-	-	-	1.4052	-
2000	.0664	NG	-	.0664	-	-	-	-	-	-	.7650	-
2200	.0468	NG	-	.0468	-	-	-	-	-	-	-.0689	-
2400	-.0429	NG	-	-.0429	-	-	-	-	-	-	-.7222	-
2600	-.0440	NG	-	-.0440	-	-	-	-	-	-	-.7927	-
2800	-.0856	NG	-	-.0856	-	-	-	-	-	-	-1.0672	-

Pressures and stresses in lb./sq.in. Strains given in inches per inch x 10^{-3}

TABLE NO. XIX

Relation of load to $p.\frac{R}{t}$

Test I: $\frac{R}{t} = \frac{3.84}{.4} = 9.6$

Test II: $\frac{R}{t} = \frac{3.84}{.3} = 12.8$

Test I		Test II	
p	$p.\frac{R}{t}$	p	$p.\frac{R}{t}$
500	4800	400	5120
750	7200	600	7680
1000	9600	800	10240
1250	12000	1000	12800
1500	14400	1100	14080
1600	15360	1200	15360
1700	16320	1250	16000
1800	17280	1300	16640
1900	18240	1400	17920
2000	19200	1600	20480
2050	19680	1800	23040
2150	20640	2000	25600
2200	21120	2200	28160
2300	22080	2400	30720
2400	23040	2600	33280
2500	24000	2800	35840
2600	24960		
2800	26880		
3000	28800		
3250	31200		

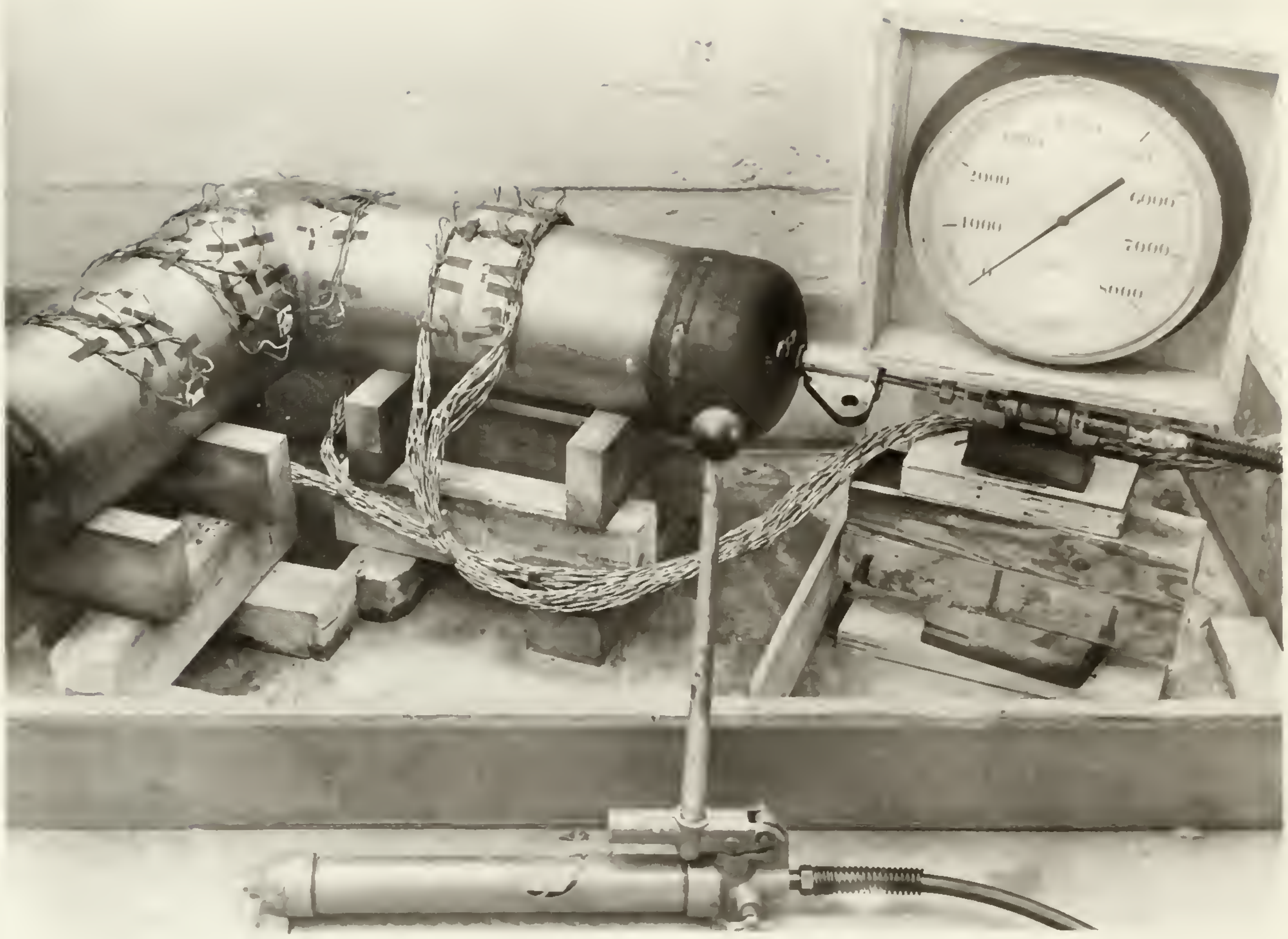


Fig. 1 First specimen and test setup.

Fig. 2 Closeup view of first specimen showing rupture.

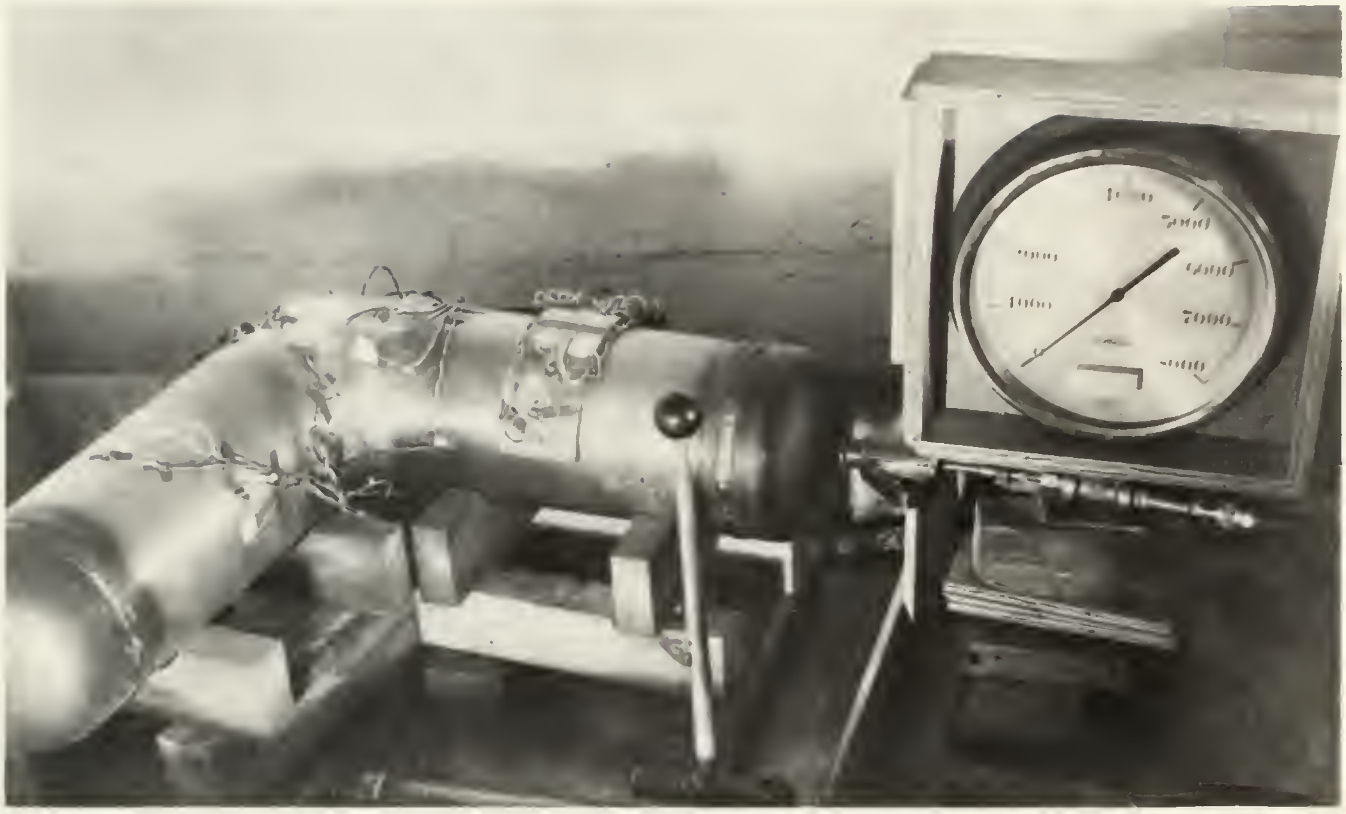


Fig. 3   Second specimen and test setup.

Fig. 4   Closeup view of second specimen showing rupture.

B-5

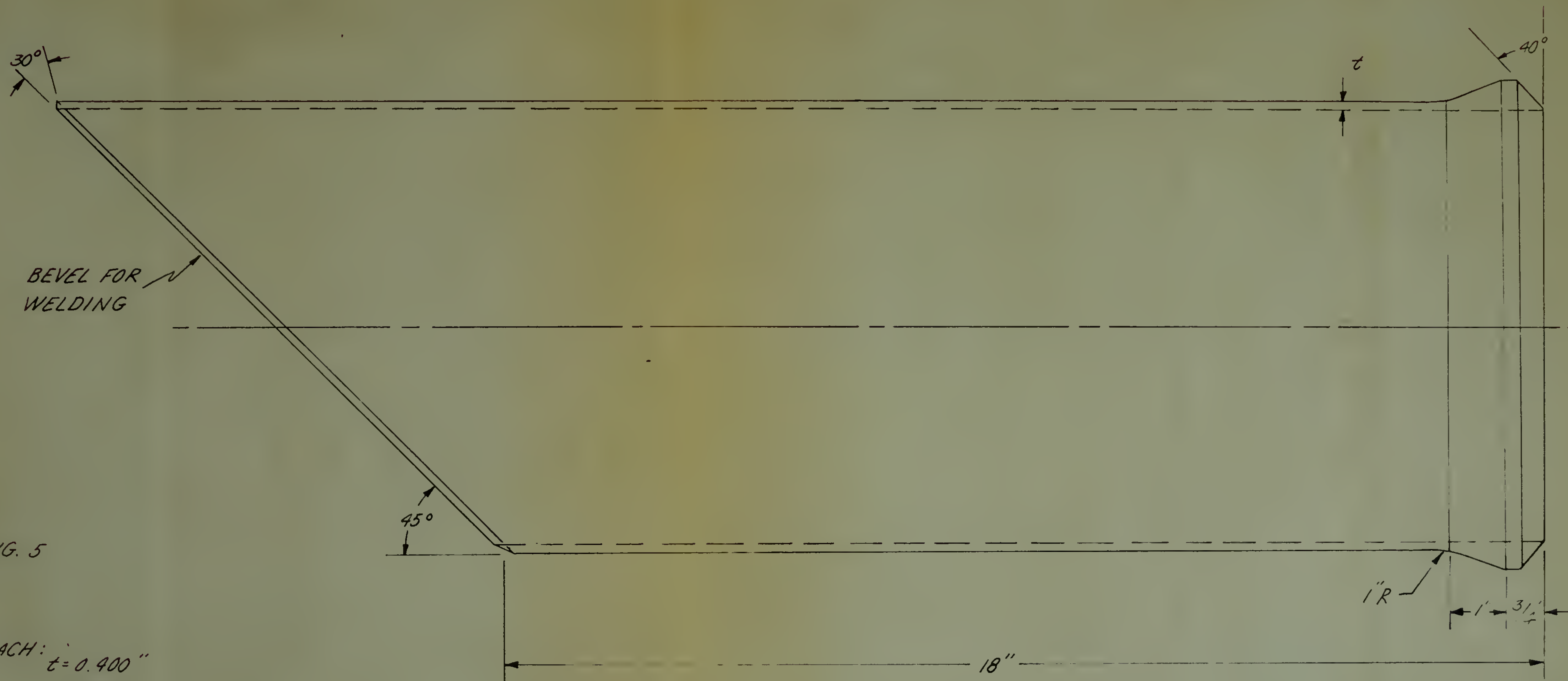


FIG. 5

NOTE:

2 EACH: t = 0.400"
t = 0.300"

MACHINE INSIDE AND OUT TO GIVE UNIFORM WALL THICKNESS WITH TOLERANCE ± .002"

MAINTAIN I.D. AS SMALL AS POSSIBLE

MATERIAL	FINISH	HEAT TREAT	DRAFTSMAN	CHECKED	APPROVED	ENGINEER	TOLERANCES = .010 OR 1/64 UNLESS OTHERWISE NOTED
8" STEEL TUBING	MACHINE						

GUGGENHEIM AERONAUTICAL LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

NAME: SPECIMENS FOR PRESSURE TESTS OF 90° CYLINDRICAL CORNER

DRAWING NO

B-6

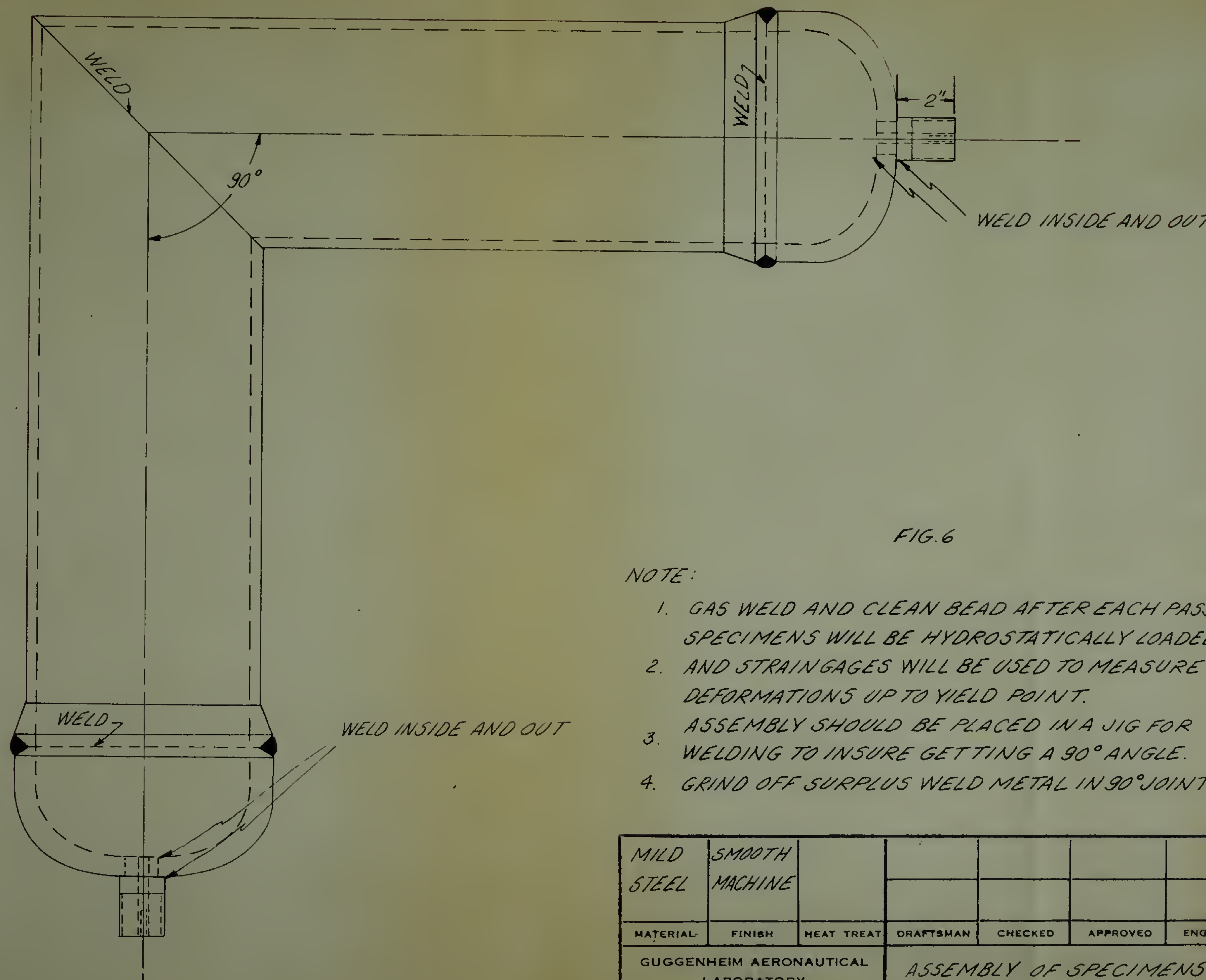


FIG. 6

NOTE:

1. GAS WELD AND CLEAN BEAD AFTER EACH PASS.
2. SPECIMENS WILL BE HYDROSTATICALLY LOADED AND STRAINGAGES WILL BE USED TO MEASURE DEFORMATIONS UP TO YIELD POINT.
3. ASSEMBLY SHOULD BE PLACED IN A JIG FOR WELDING TO INSURE GETTING A 90° ANGLE.
4. GRIND OFF SURPLUS WELD METAL IN 90° JOINT.

MILD STEEL	SMOOTH MACHINE						TOLERANCES ± .010 OR 1/64 UNLESS OTHERWISE NOTED SCALE: 1/4
MATERIAL	FINISH	HEAT TREAT	DRAFTSMAN	CHECKED	APPROVED	ENGINEER	
GUGGENHEIM AERONAUTICAL LABORATORY CALIFORNIA INSTITUTE OF TECHNOLOGY			ASSEMBLY OF SPECIMENS FOR PRESSURE TESTS				
			NAME				DRAWING NO.

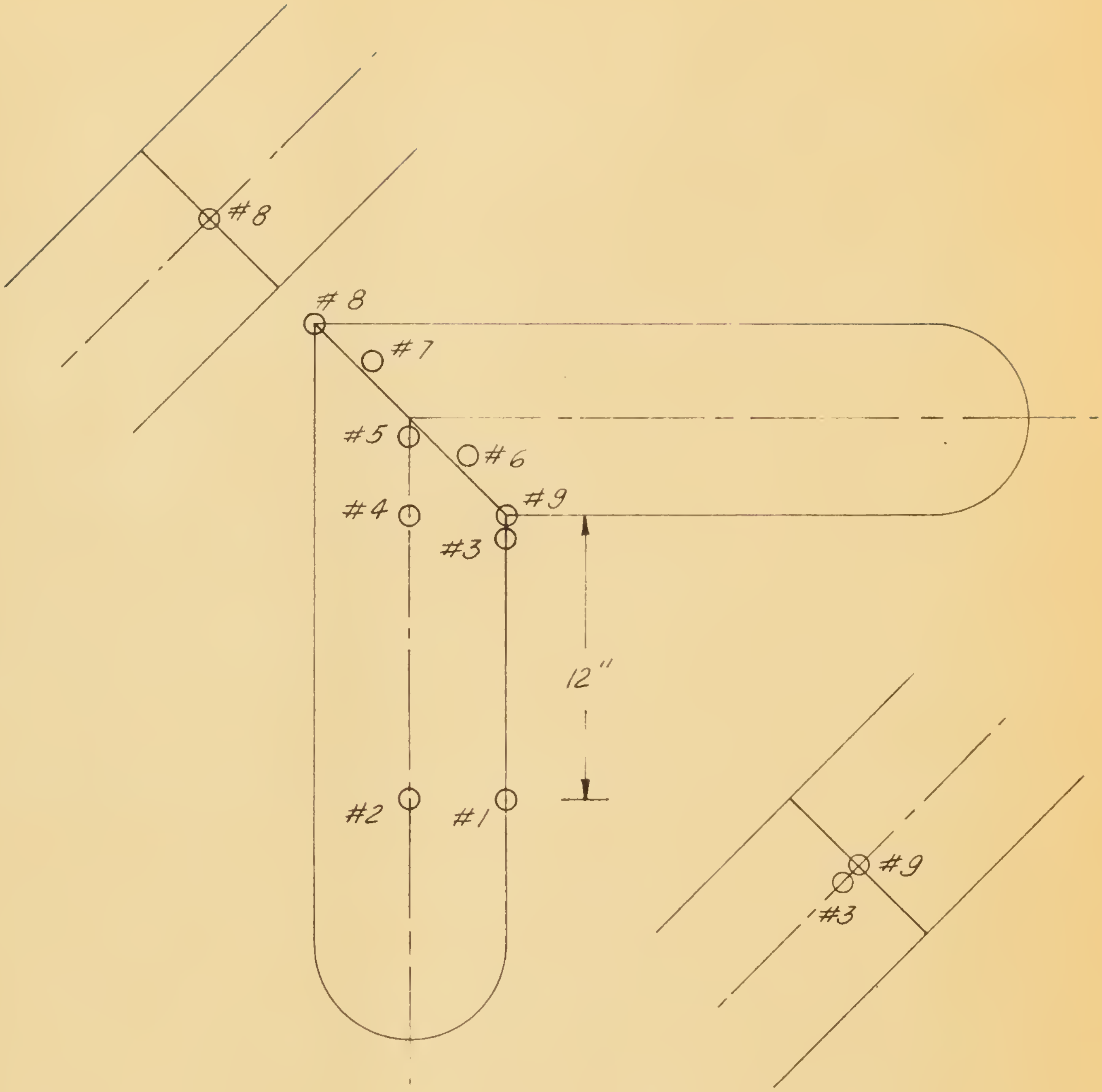


FIG. 7

LOCATION OF STRAIN GAGES
TESTS I AND II

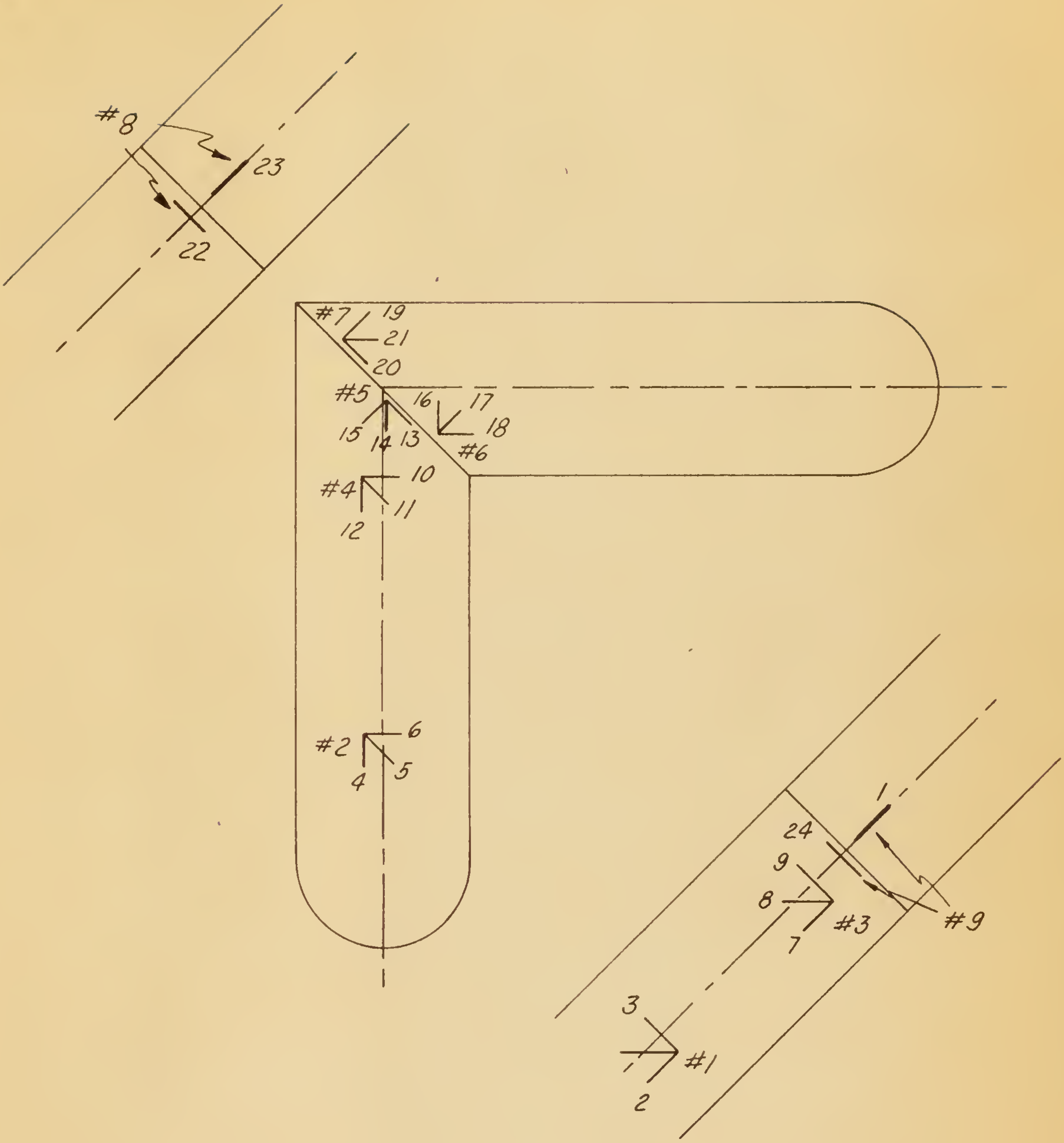


FIG. 8

ORIENTATION OF STRAIN GAGES, TEST I

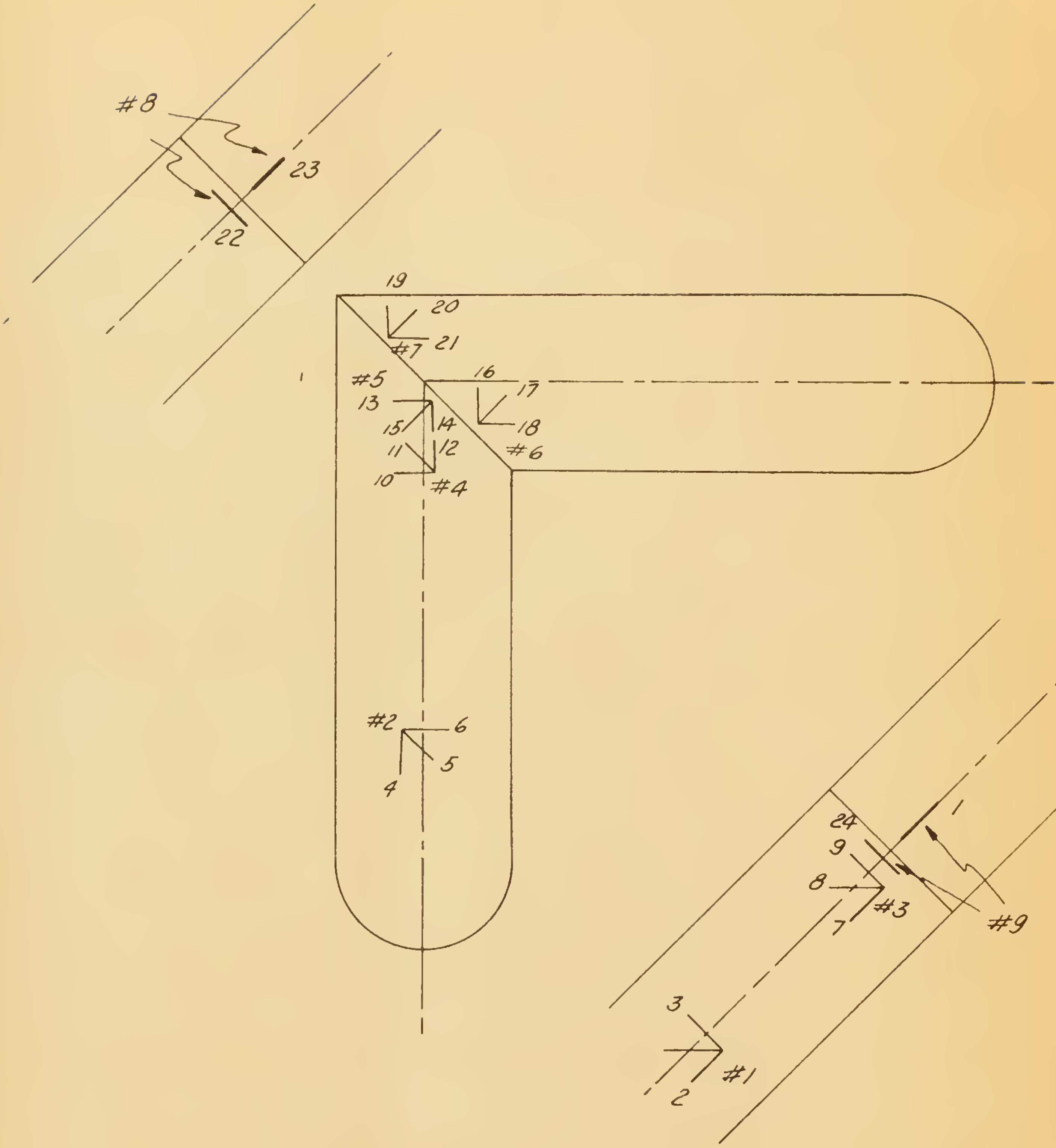


FIG. 9

ORIENTATION OF STRAIN GAGES, TEST II

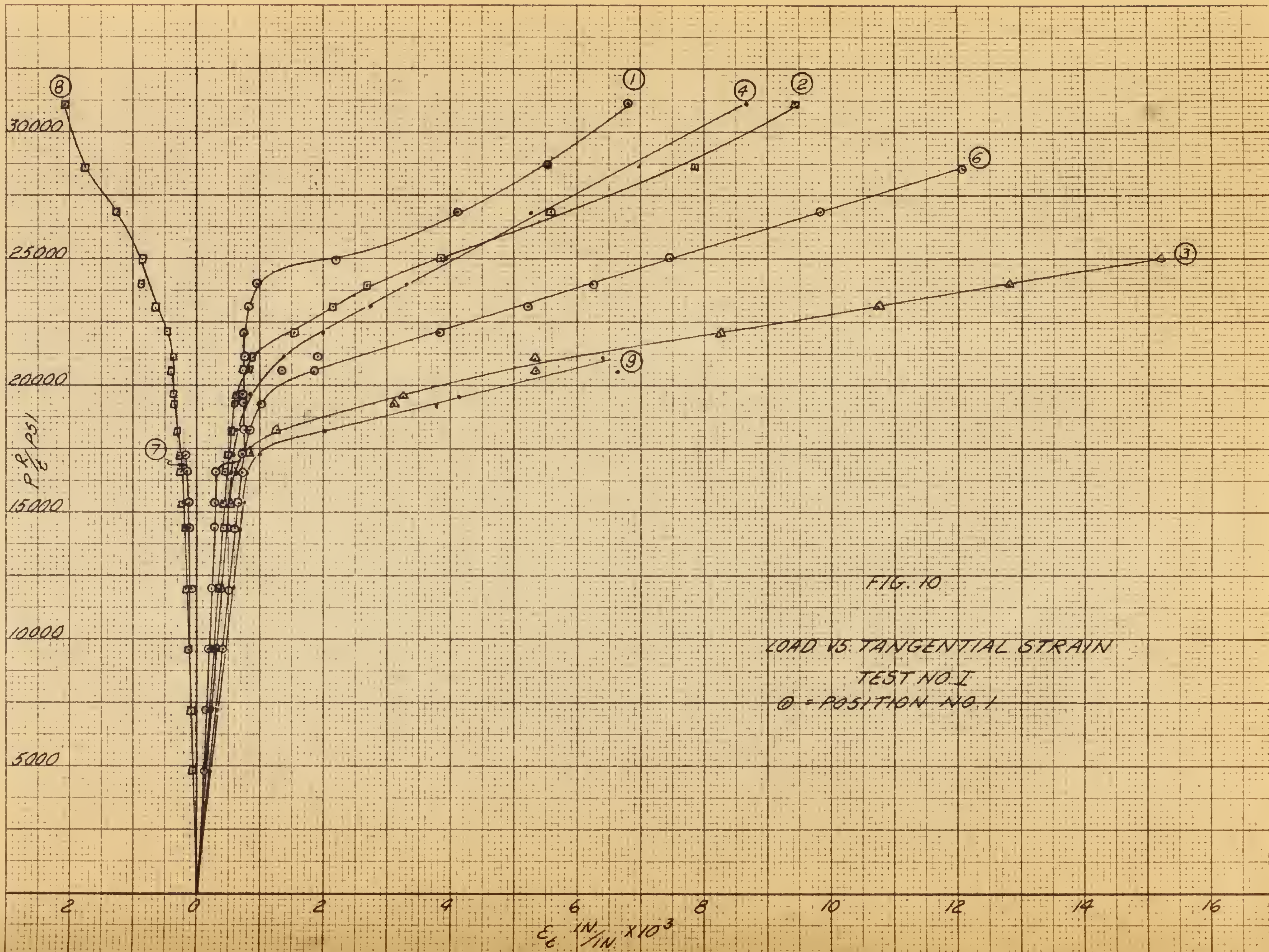


FIG. 10

LOAD VS. TANGENTIAL STRAIN

TEST NO. I

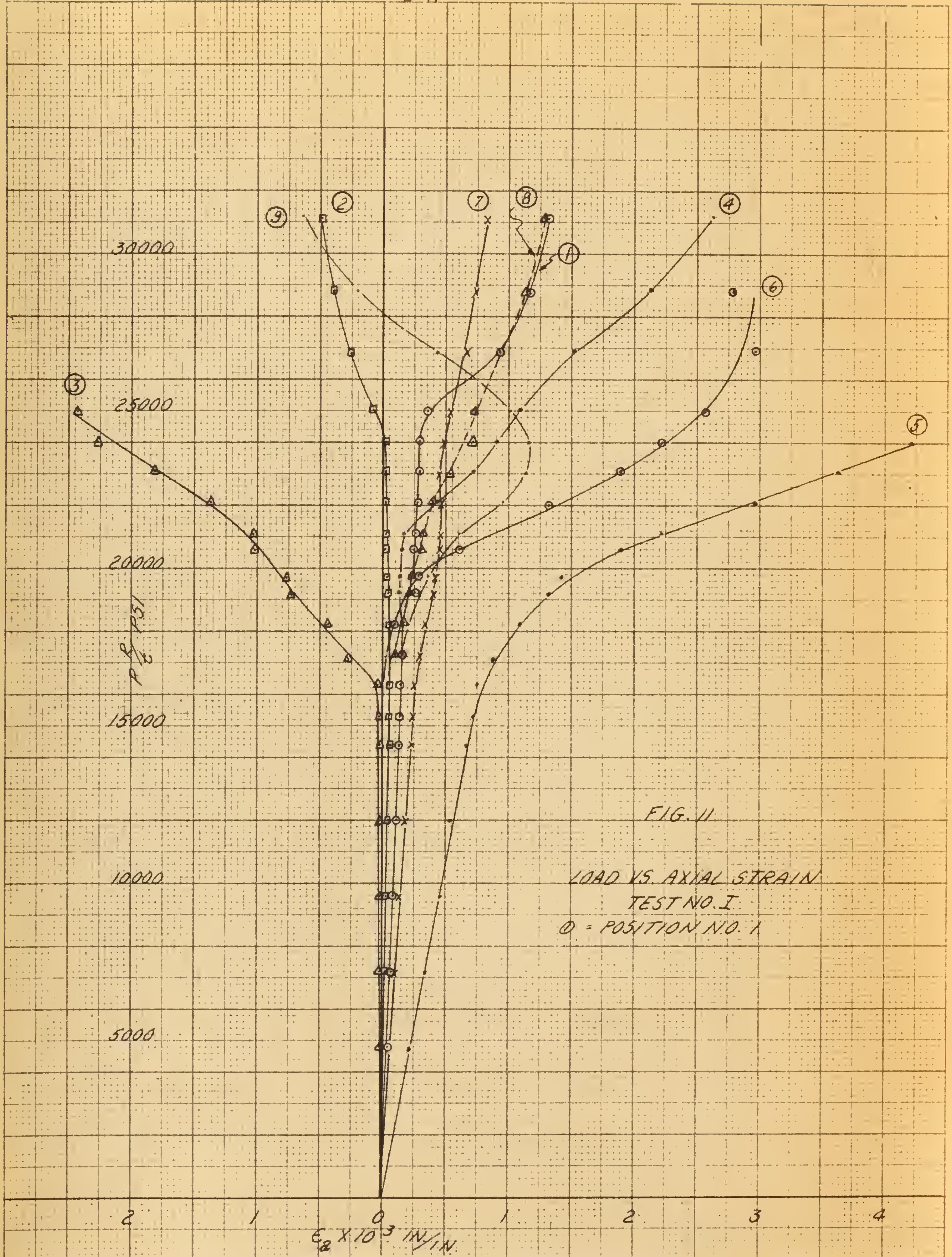


FIG. 11

LOAD VS. AXIAL STRAIN
TEST NO. I
⊙ = POSITION NO. 1

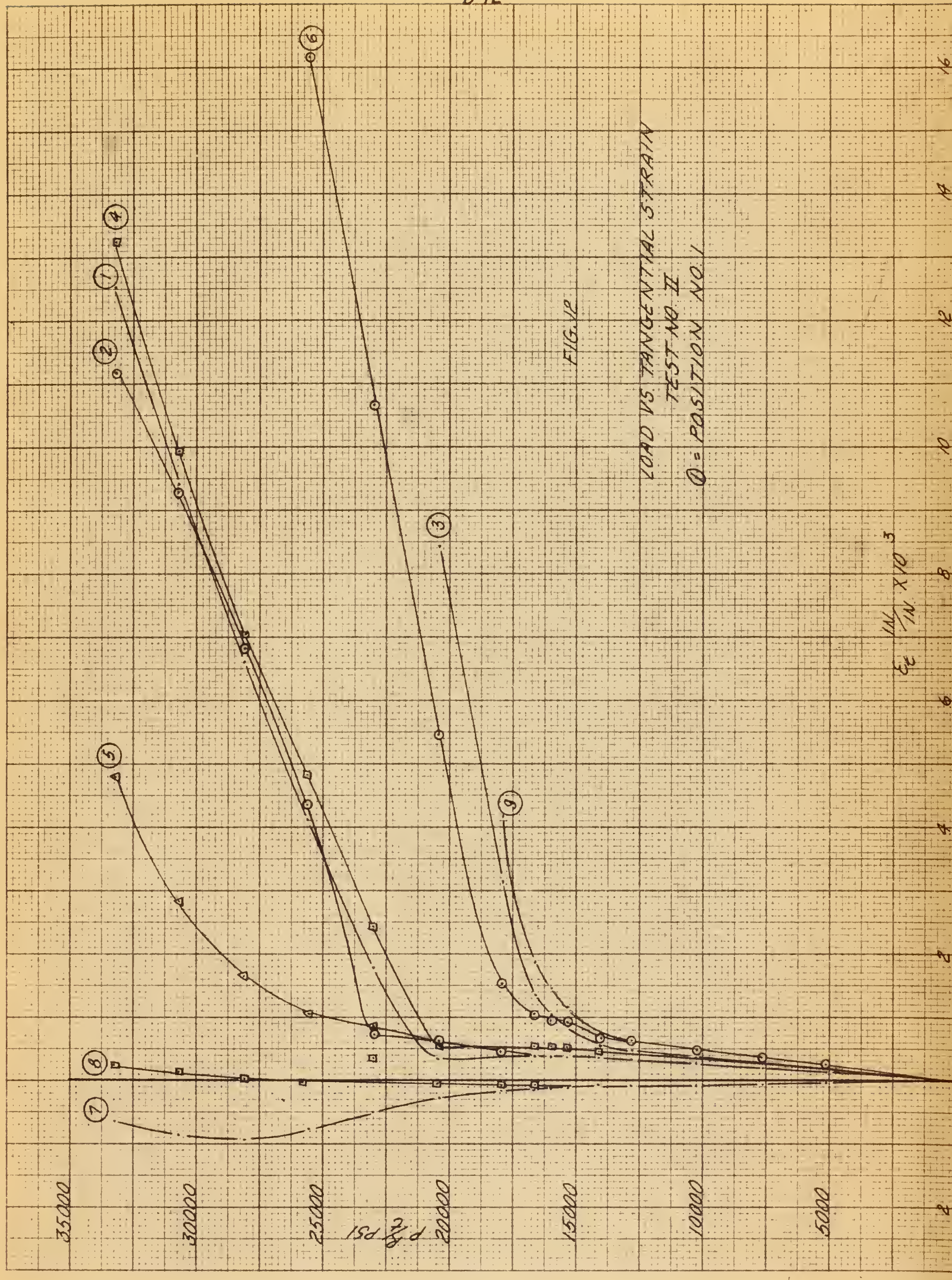


FIG. 12
LOAD VS TANGENTIAL STRAIN
TEST NO. II
① = POSITION NO. 1
ε_t IN/IN. X 10^-3
P/A PSI
35000
30000
25000
20000
15000
10000
5000
2
4
6
8
10
12
14
16
1
2
3
4
5
6
7
8
9

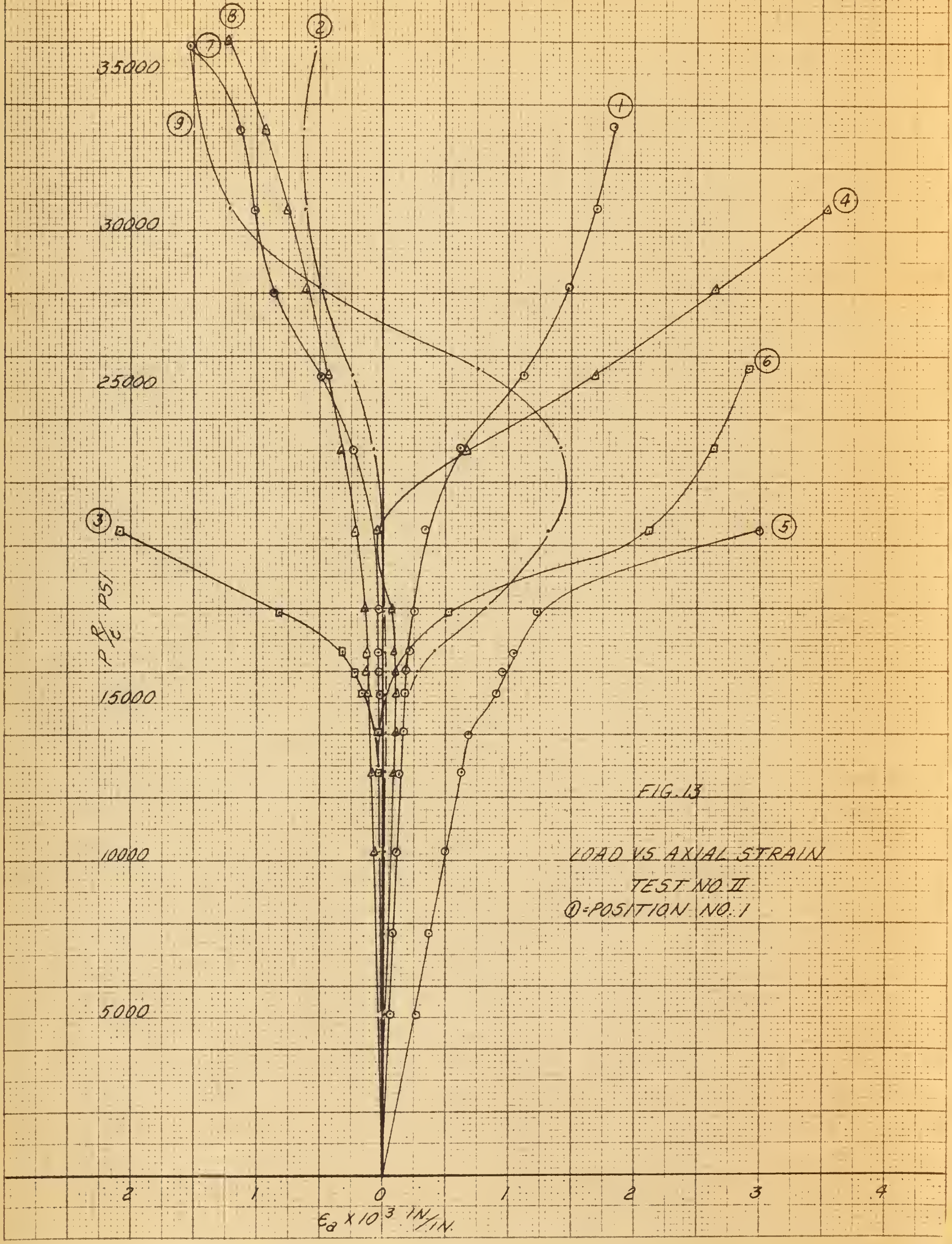


FIG. 13

LOAD VS. AXIAL STRAIN

TEST NO. II

① = POSITION NO. 1

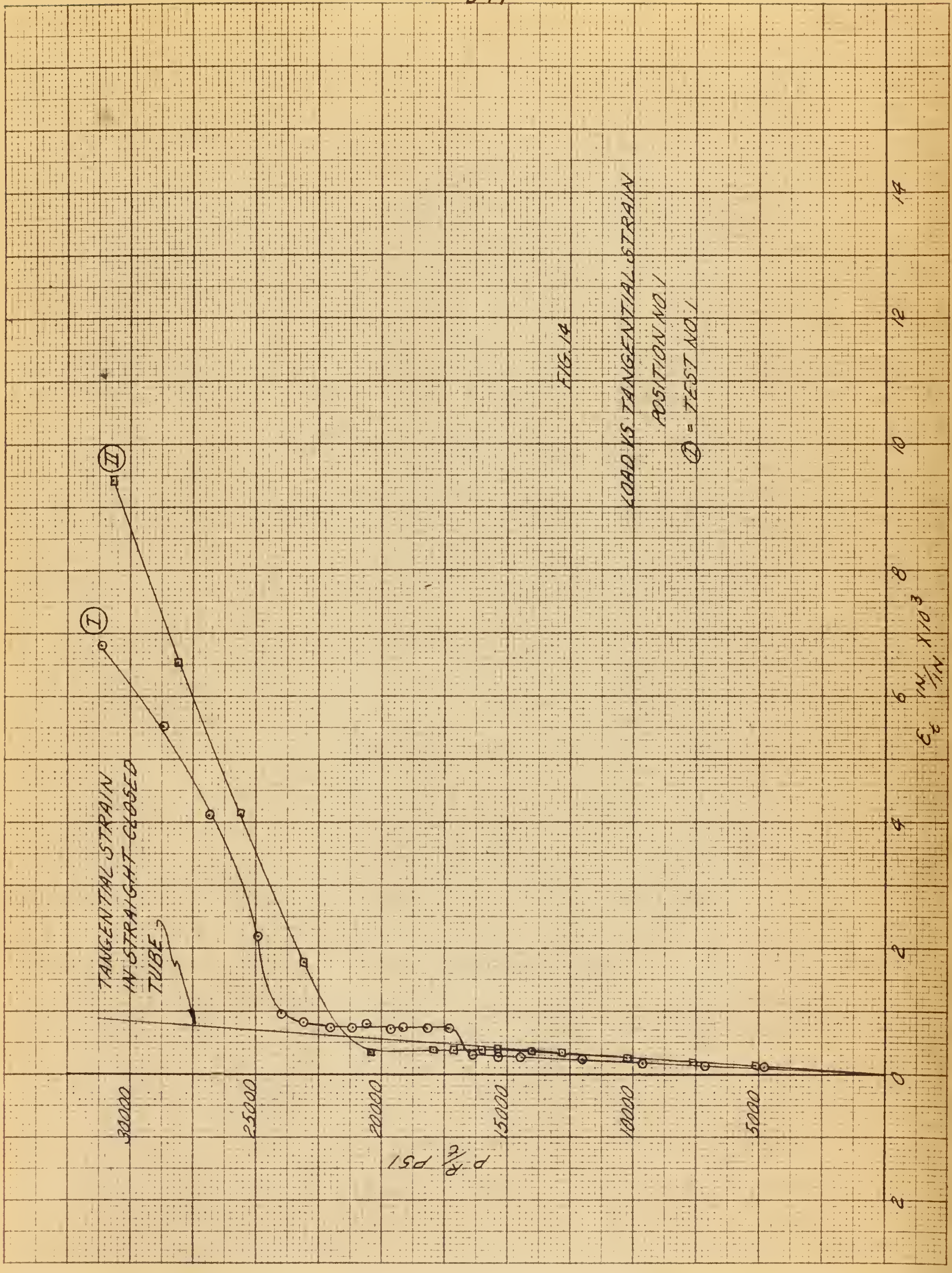
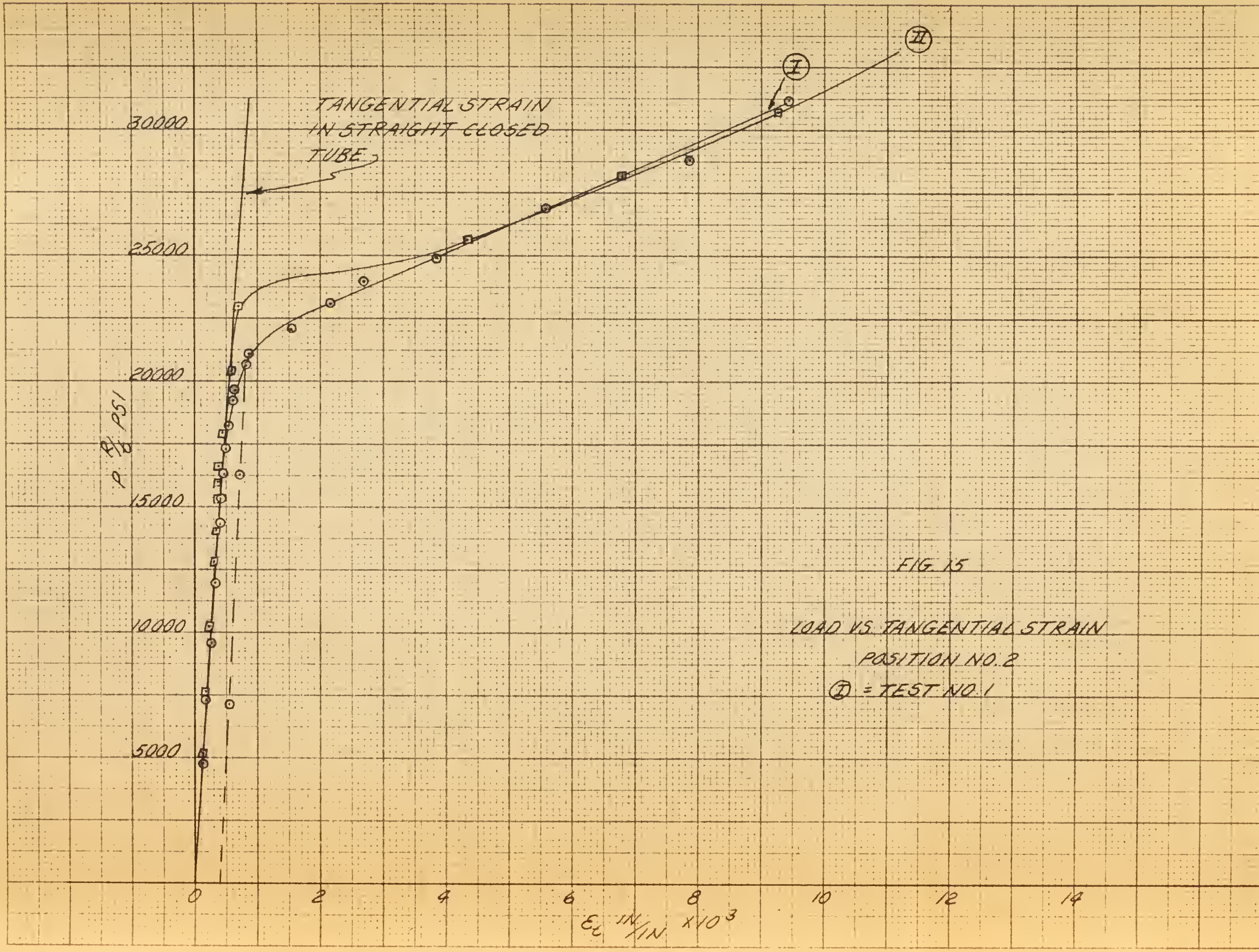


FIG. 14
LOAD VS TANGENTIAL STRAIN
POSITION NO. 1
(I) = TEST NO. 1
TANGENTIAL STRAIN IN STRAIGHT CLOSED TUBE
I
II
30000
25000
20000
15000
10000
5000
P R/t PSI
0
2
4
6
8
10
12
14
2
ε_t IN/IN X10^3



TANGENTIAL STRAIN IN STRAIGHT CLOSED TUBE
I
II
30000
25000
20000
15000
10000
5000
P R/t PSI
0
2
4
6
8
10
12
14
ε_t IN/IN $\times 10^3$
LOAD VS. TANGENTIAL STRAIN
POSITION NO. 2
I = TEST NO. 1

FIG. 15

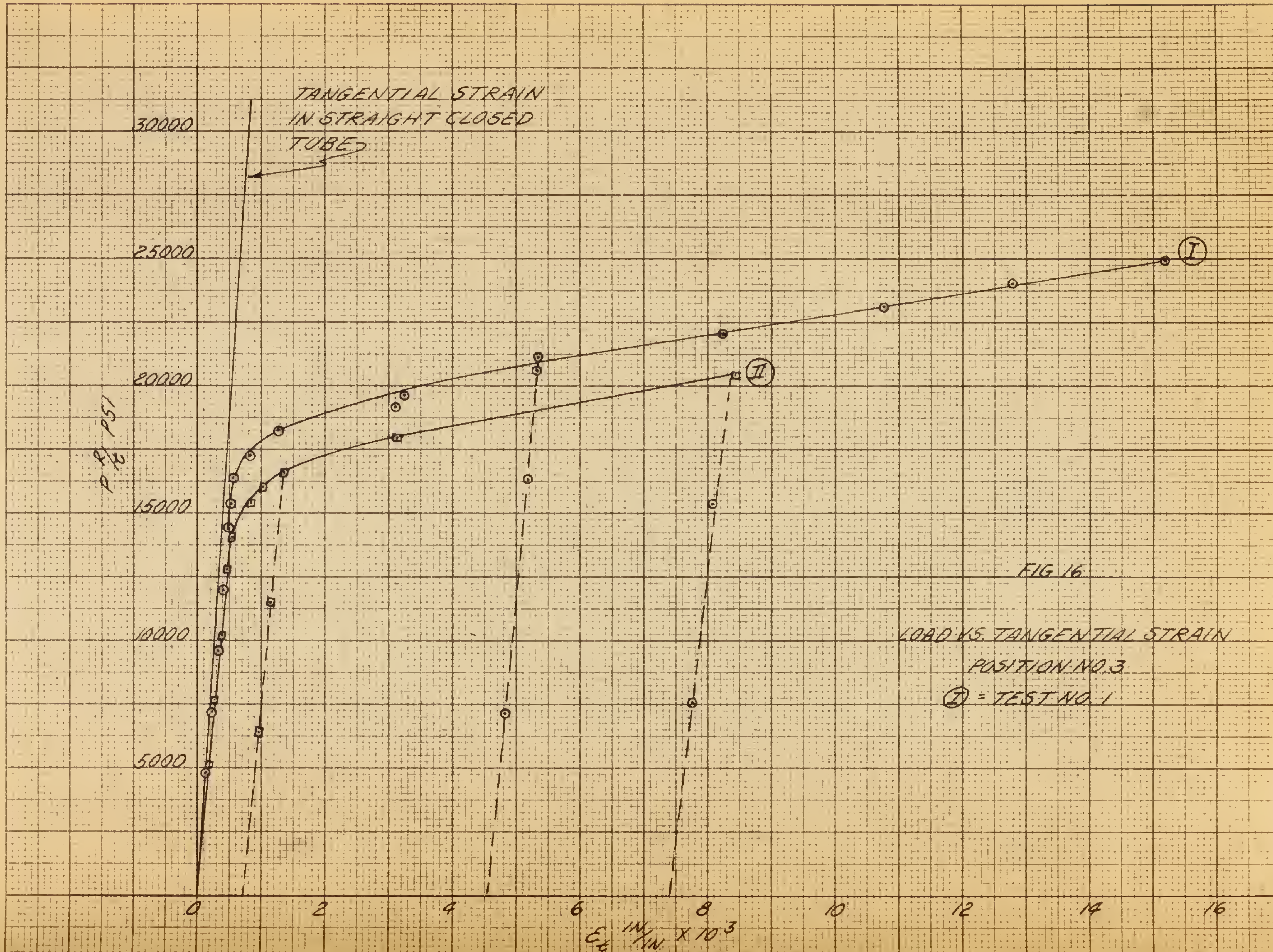


FIG. 16

LOAD VS. TANGENTIAL STRAIN

POSITION NO. 3

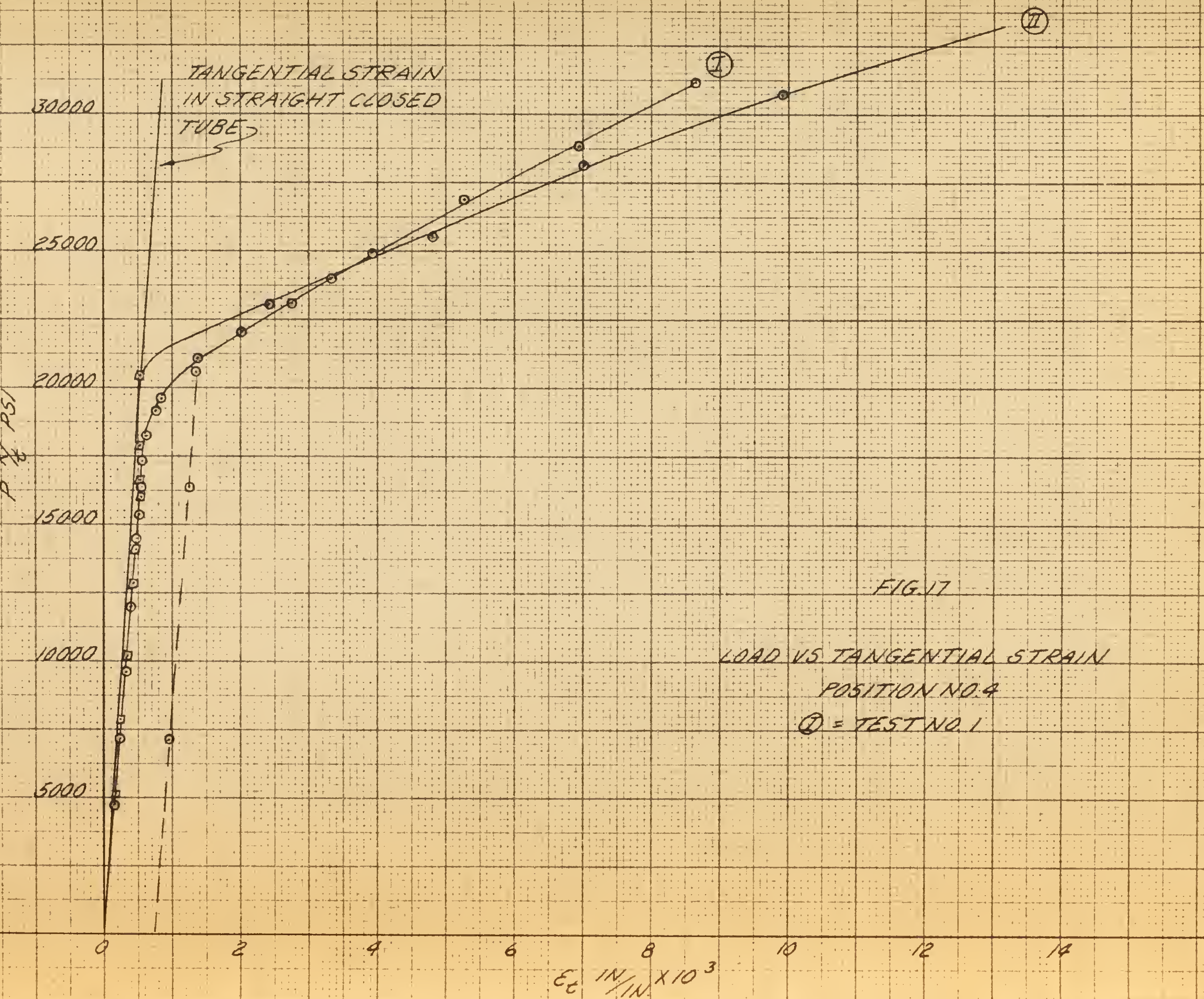


FIG. 17

LOAD VS TANGENTIAL STRAIN
POSITION NO. 4
① = TEST NO. 1

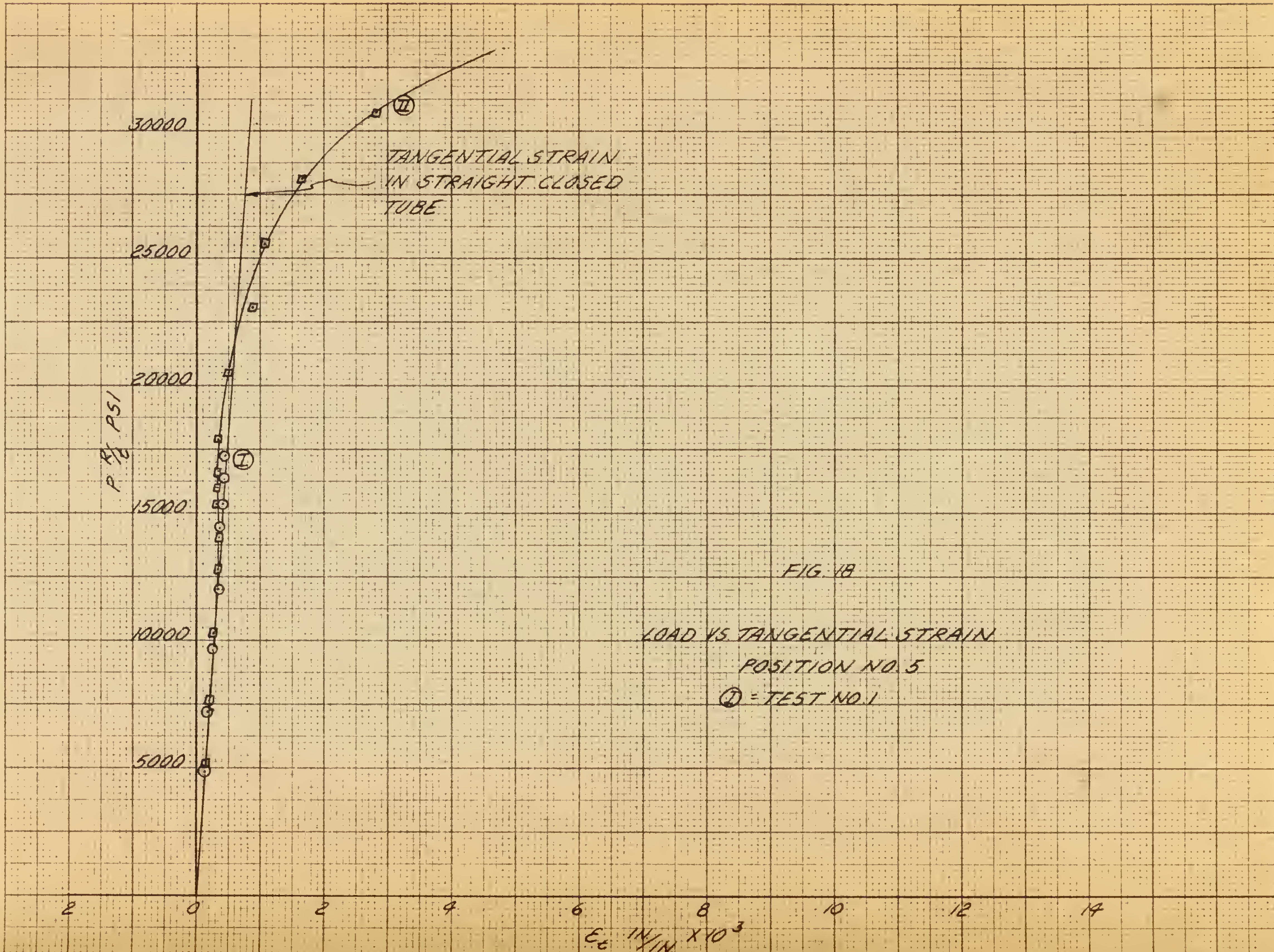


FIG. 18

LOAD VS. TANGENTIAL STRAIN

POSITION NO. 5

I = TEST NO. 1

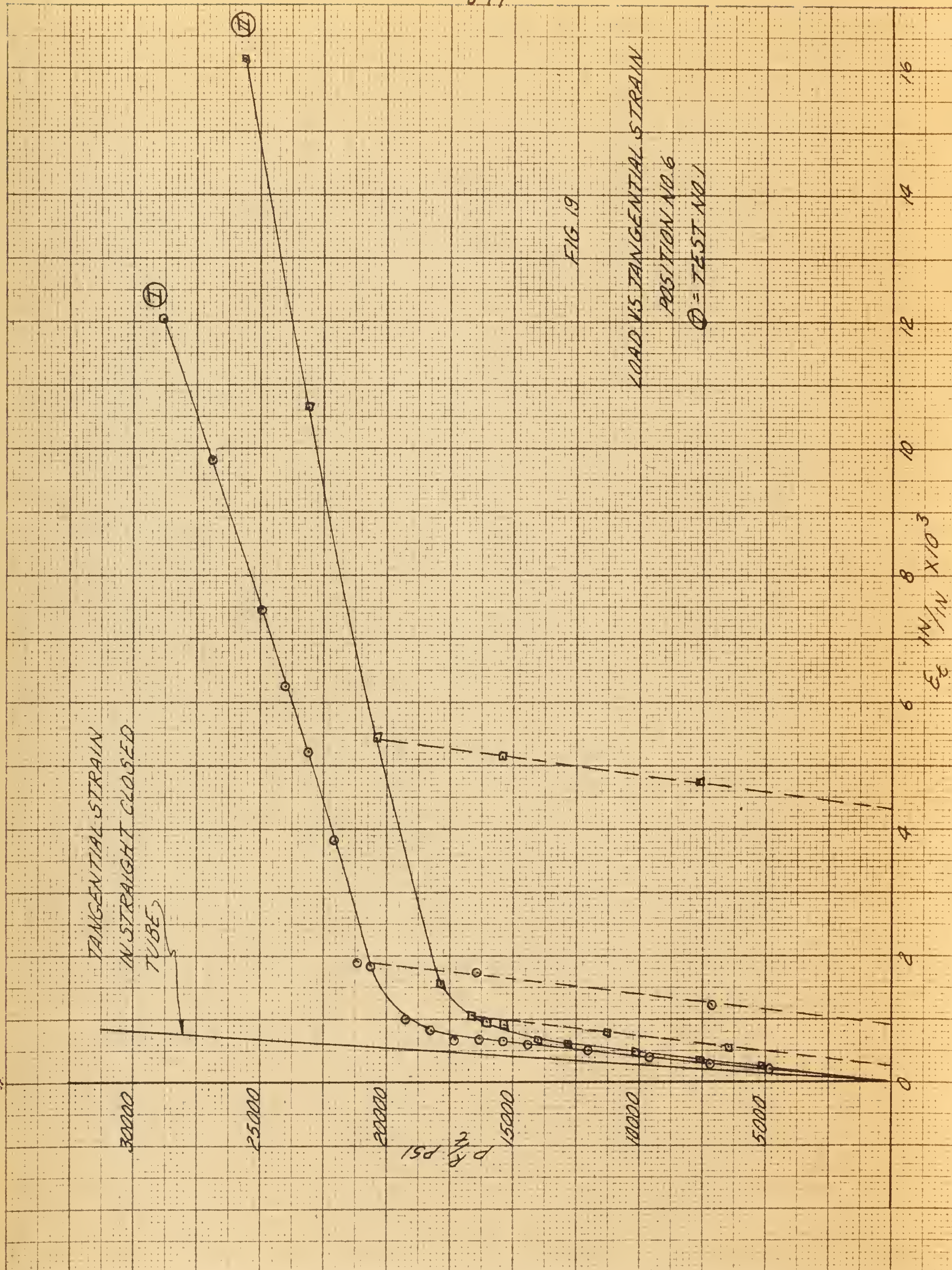


FIG. 19
LOAD VS TANGENTIAL STRAIN
POSITION NO. 6
Ⓘ = TEST NO. I
TANGENTIAL STRAIN IN STRAIGHT CLOSED TUBE
I
II
30000
25000
20000
15000
10000
5000
PSI
0
2
4
6
8
10
12
14
16
ε_t IN/IN X10^3

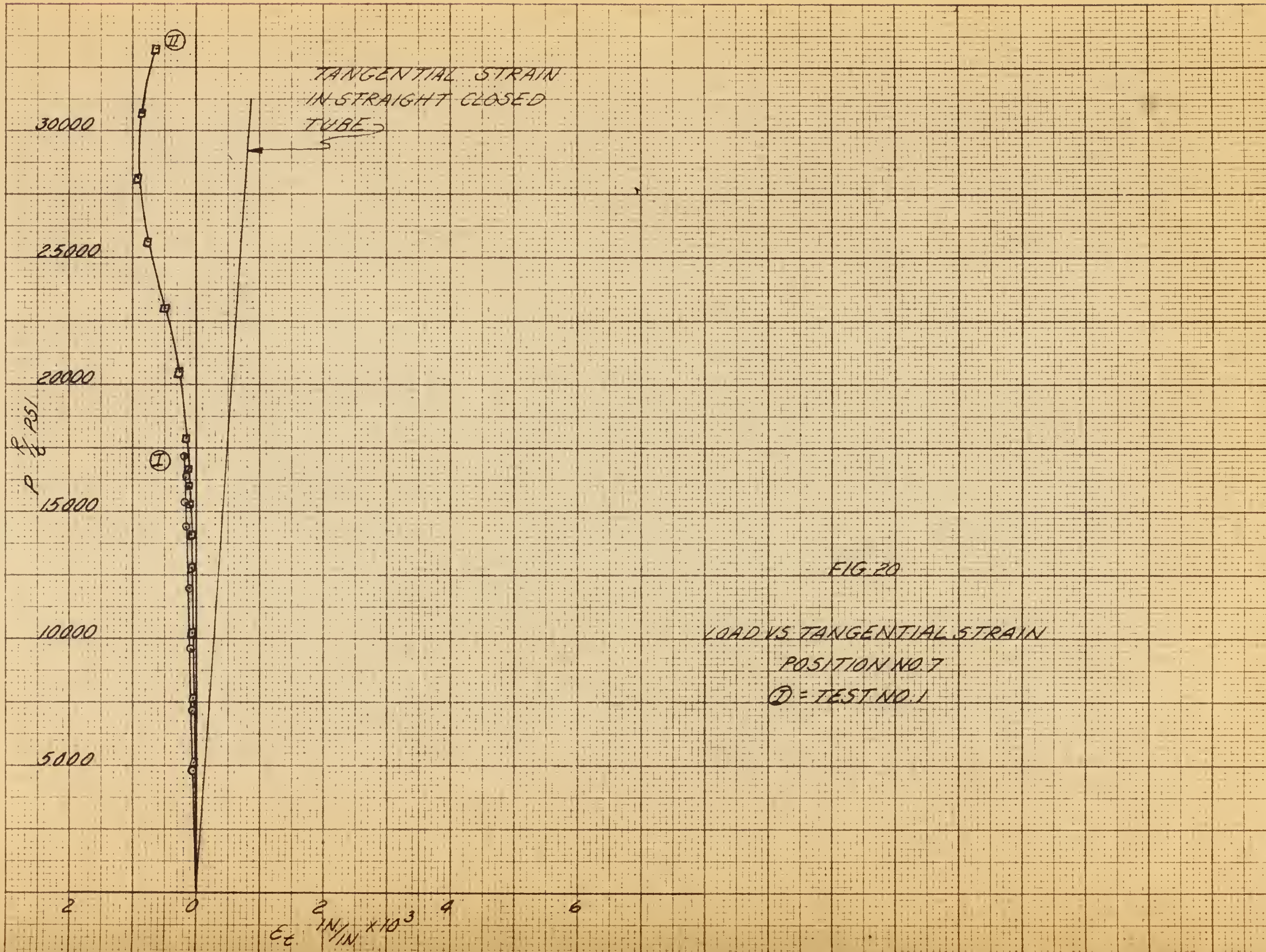


FIG. 20

LOAD VS TANGENTIAL STRAIN
POSITION NO. 7
I = TEST NO. 1

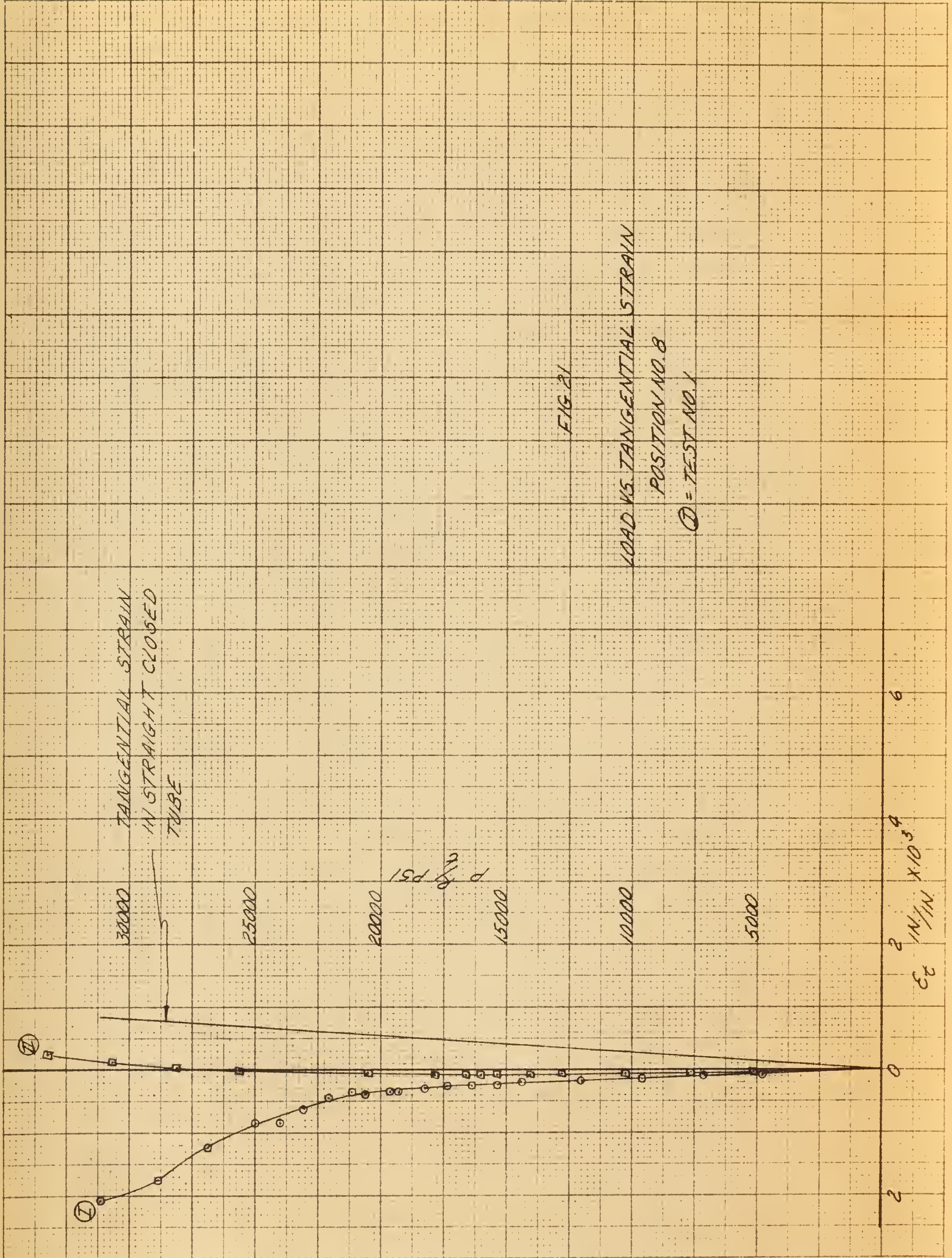


FIG. 21
LOAD VS. TANGENTIAL STRAIN
POSITION NO. 8
I = TEST NO. 1
TANGENTIAL STRAIN IN STRAIGHT CLOSED TUBE
P, PSI
30000
25000
20000
15000
10000
5000
ε_t IN/IN X10^-3
0
2
4
6
I
II

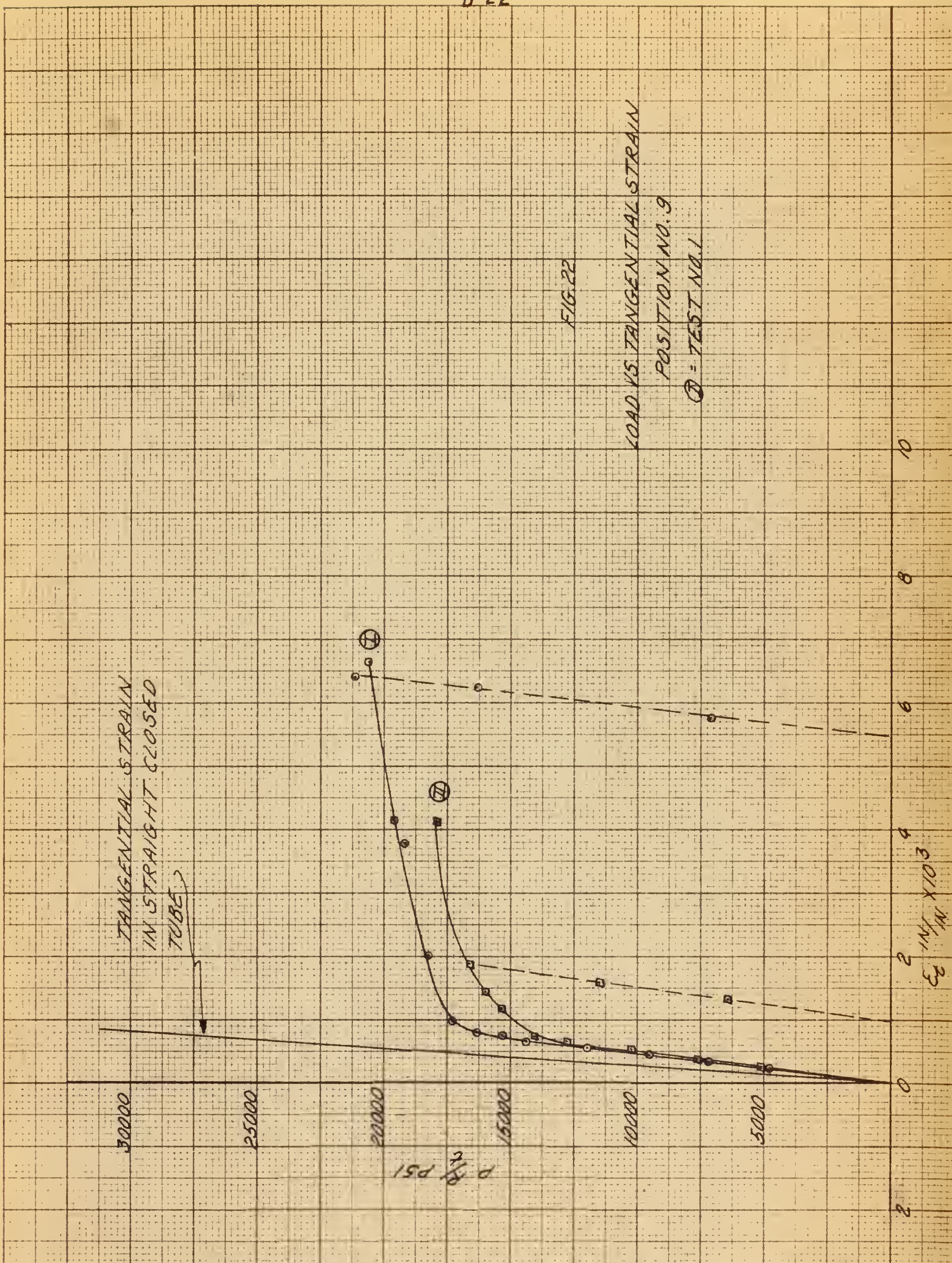


FIG. 22
LOAD VS TANGENTIAL STRAIN
POSITION NO. 9
① = TEST NO. 1
TANGENTIAL STRAIN IN STRAIGHT CLOSED TUBE
I
II
30000
25000
20000
15000
10000
5000
P R/t PSI
0
2
4
6
8
10
ε IN/IN X10³

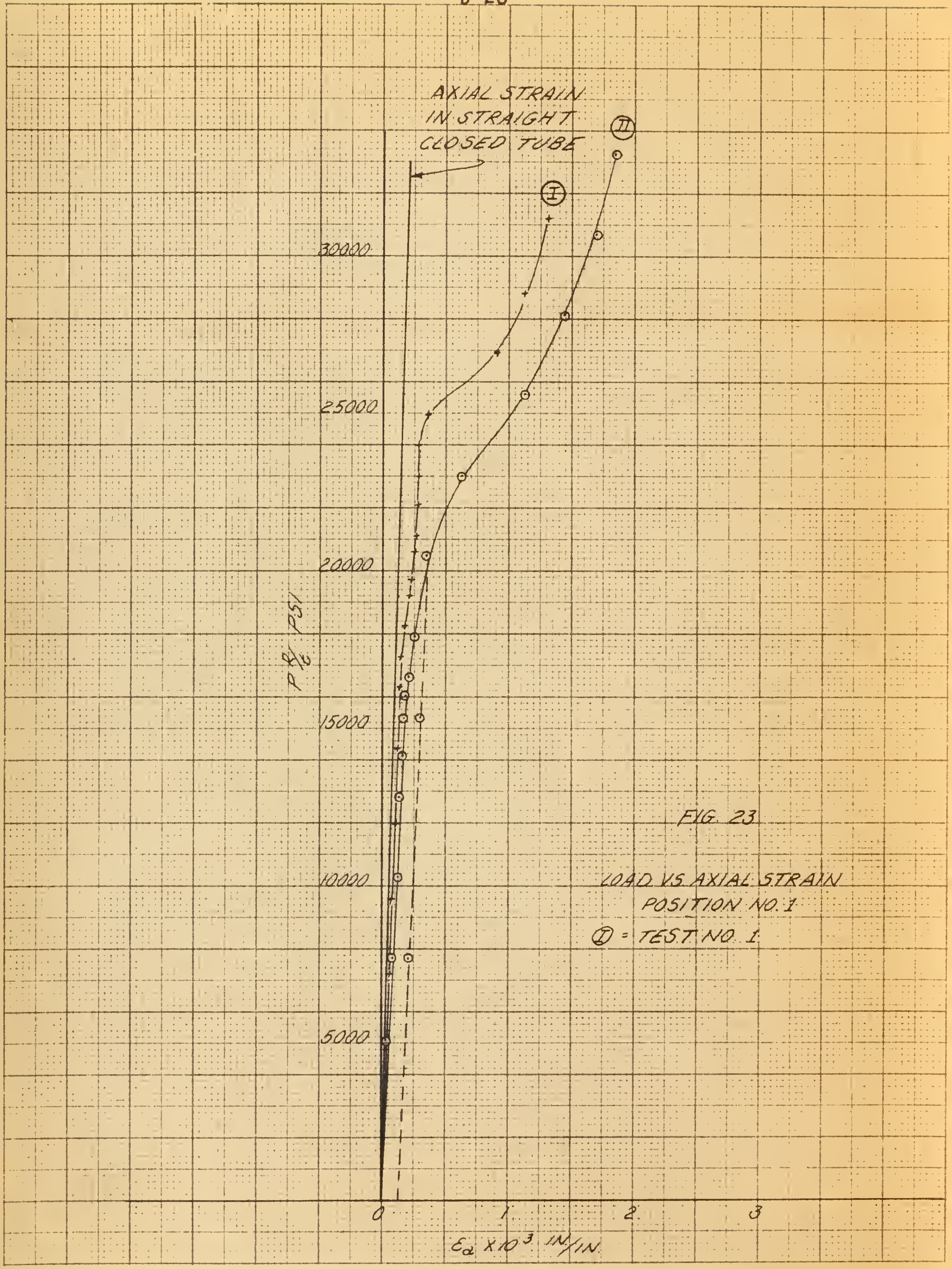

AXIAL STRAIN
IN STRAIGHT
CLOSED TUBE
II
I
30000
25000
20000
$P\frac{R}{t}$ PSI
15000
10000
5000
0
1
2
3
$\varepsilon_a \times 10^3$ IN/IN
LOAD VS. AXIAL STRAIN
POSITION NO. 1
I = TEST NO. 1

FIG. 23

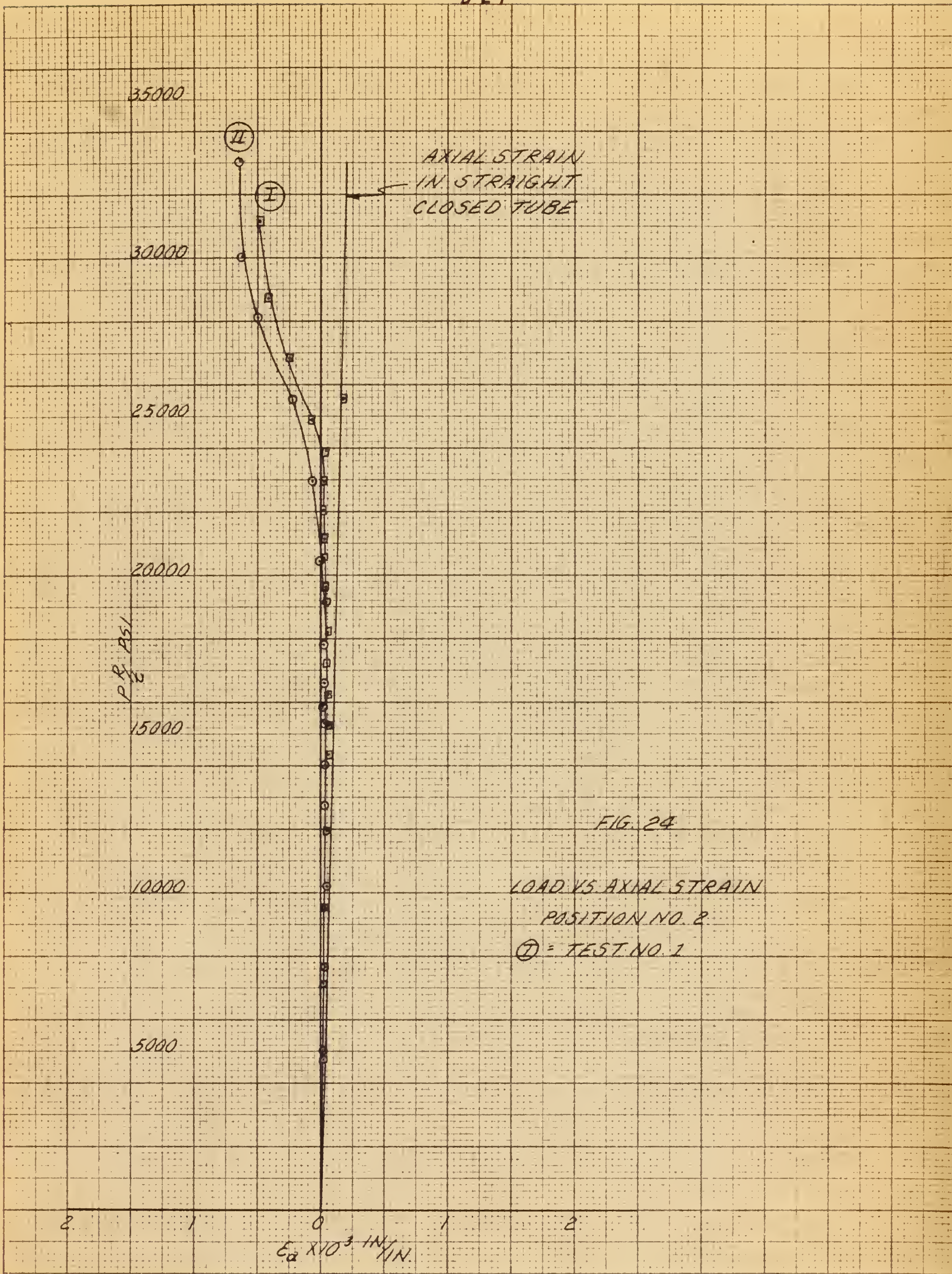


FIG. 24

LOAD VS. AXIAL STRAIN

POSITION NO. 2

(I) = TEST NO. 1

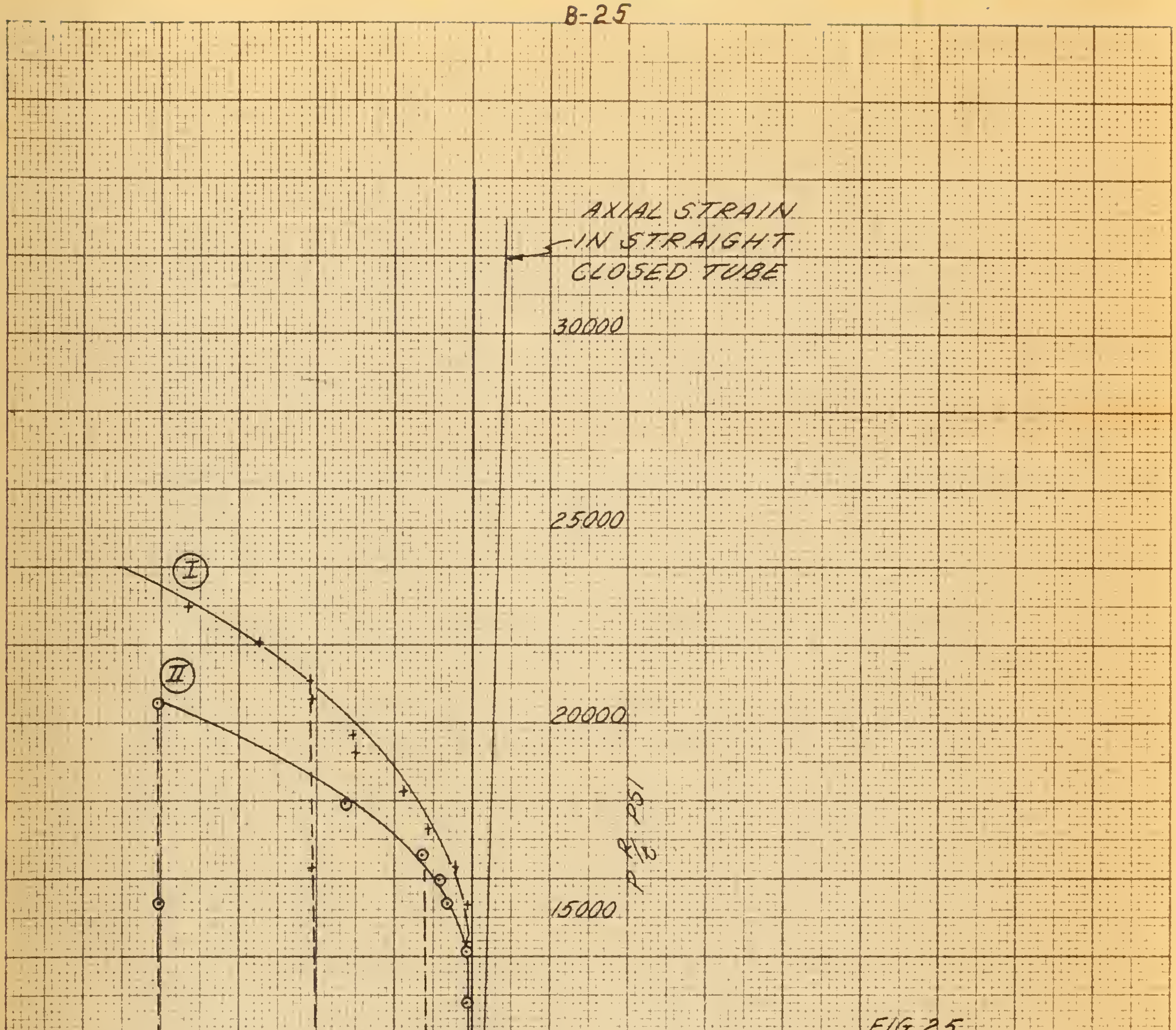
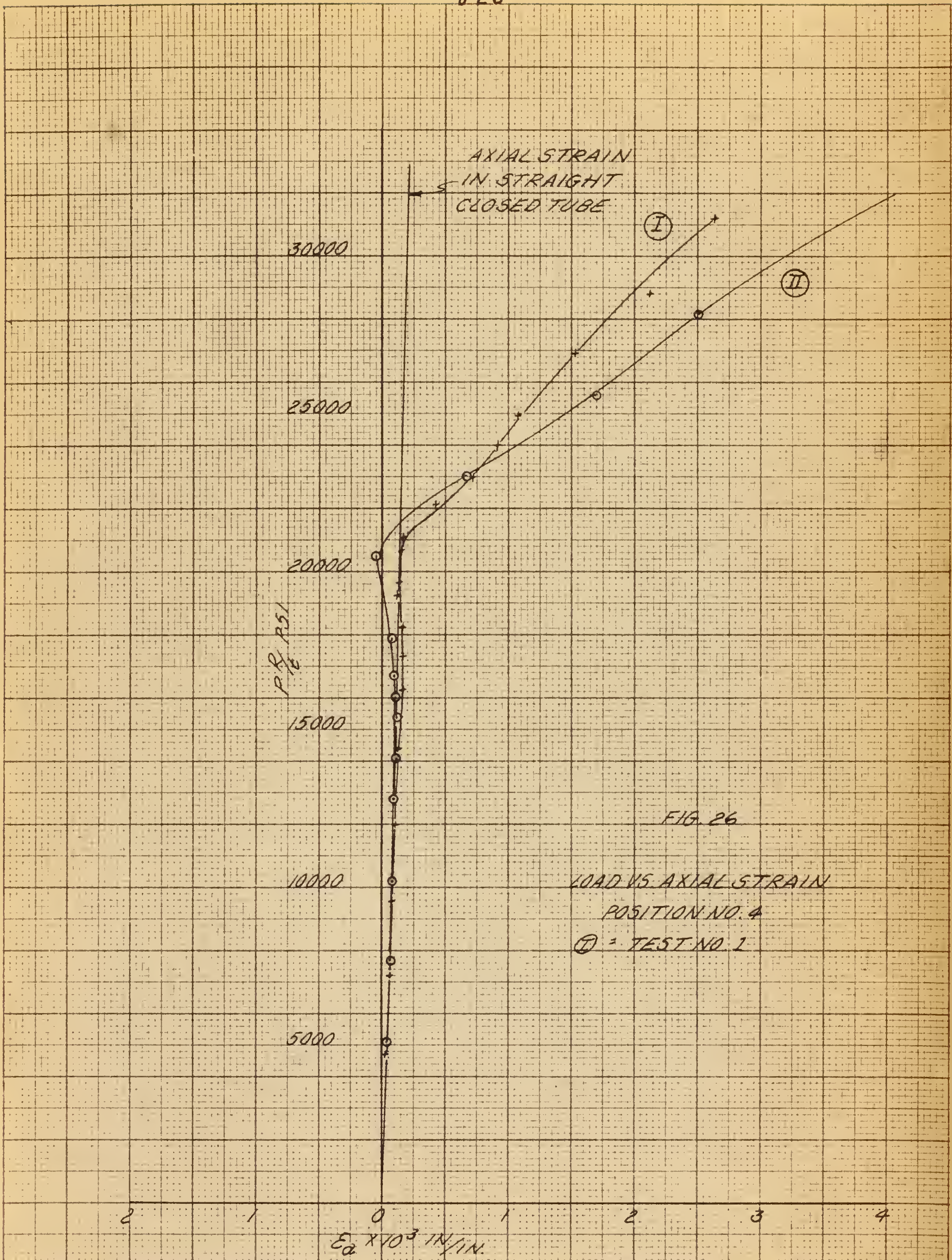


FIG. 25

LOAD VS. AXIAL STRAIN

POSITION NO. 3

I = TEST NO. 1


AXIAL STRAIN
IN STRAIGHT
CLOSED TUBE
I
II
30000
25000
20000
15000
10000
5000
$P \frac{R}{t}$ PSI
2
1
0
1
2
3
4
$\epsilon_a \times 10^3$ IN/IN.
FIG. 26
LOAD VS. AXIAL STRAIN
POSITION NO. 4
I = TEST NO. 1

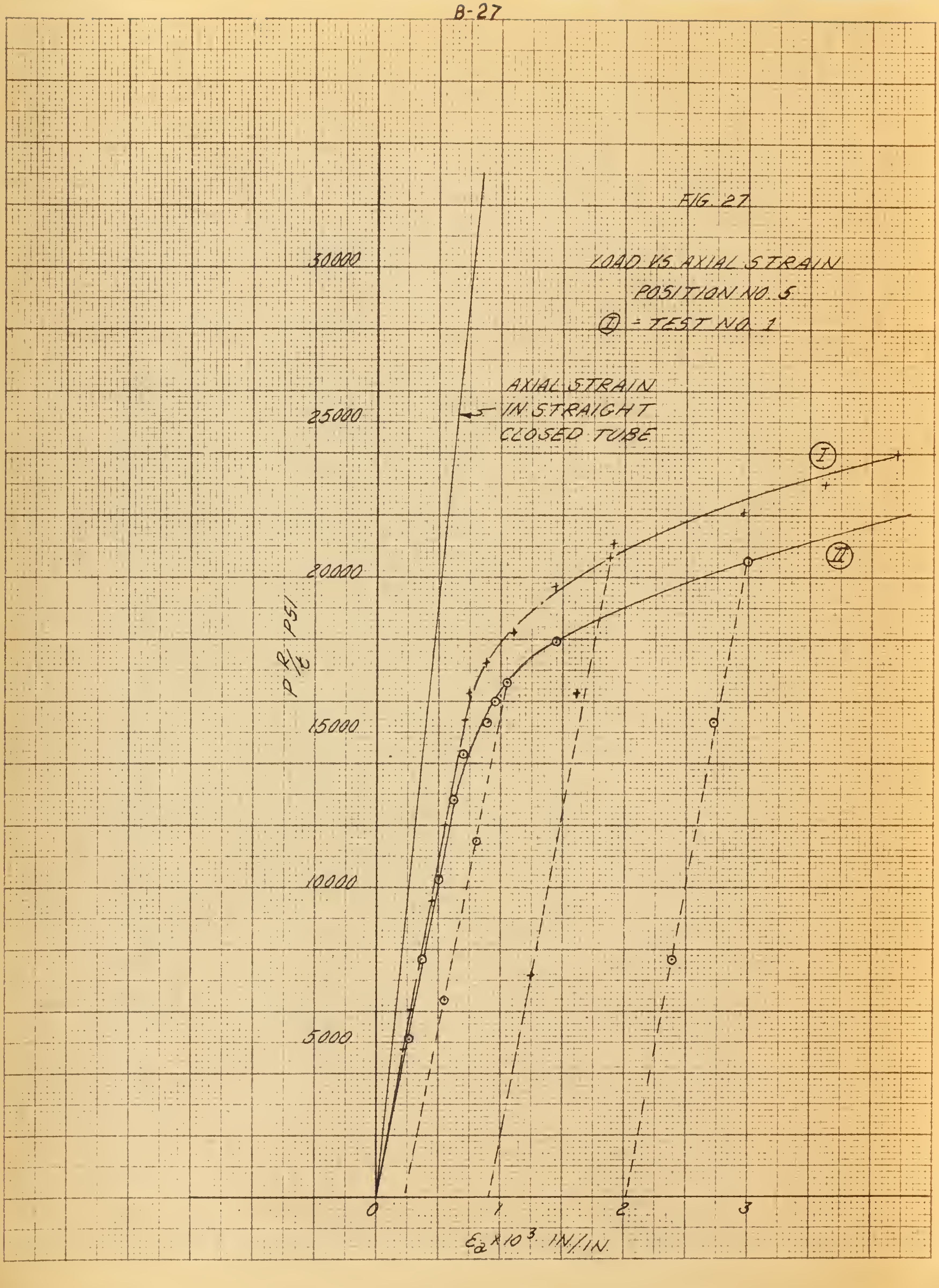


FIG. 27
LOAD VS. AXIAL STRAIN
POSITION NO. 5
(I) = TEST NO. 1
AXIAL STRAIN
IN STRAIGHT
CLOSED TUBE
I
II
30000
25000
20000
15000
10000
5000
P R/t PSI
0
1
2
3
$\varepsilon_a \times 10^3$ IN/IN.

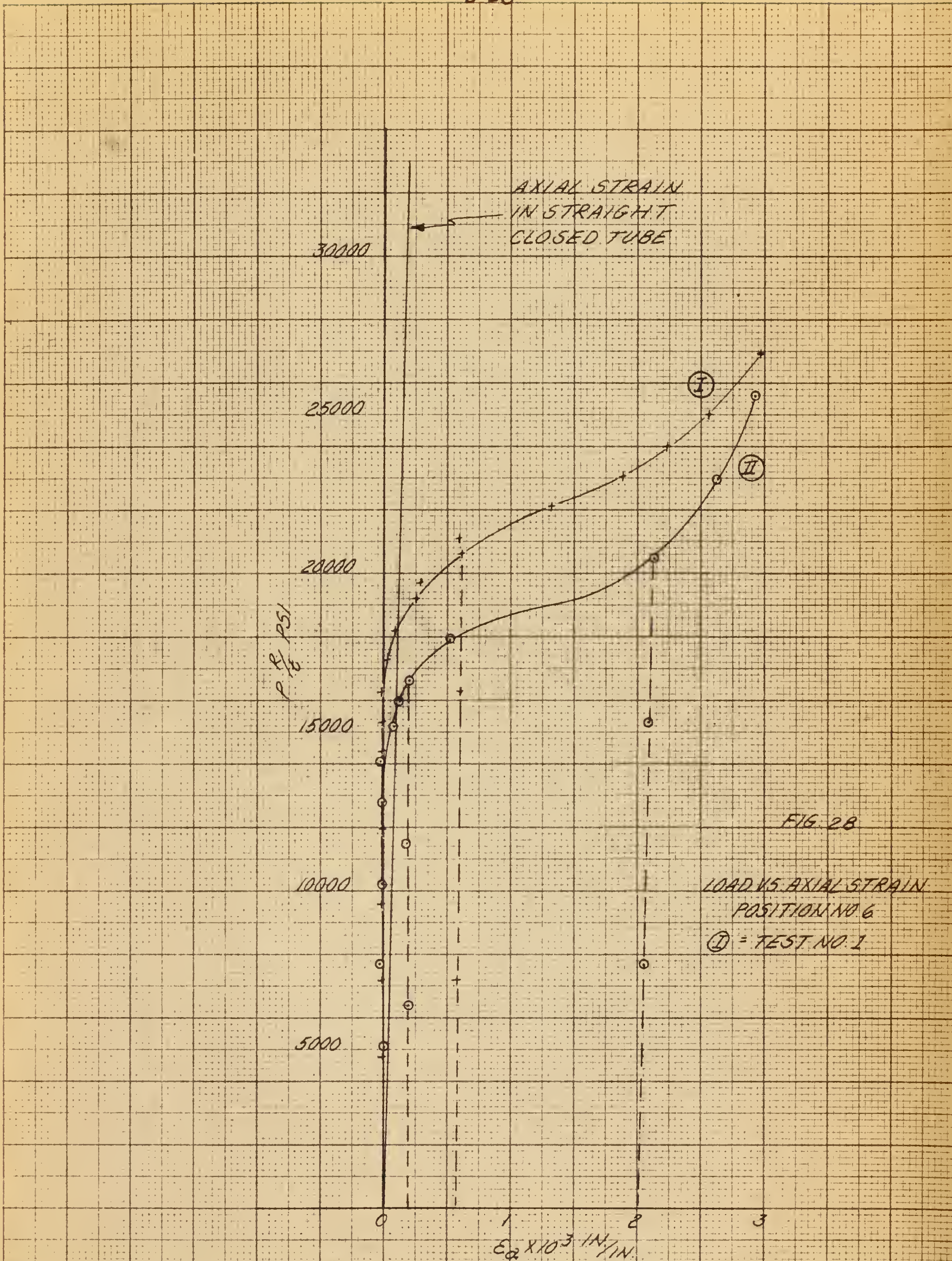


FIG. 28

LOAD VS. AXIAL STRAIN
POSITION NO. 6
Ⓘ = TEST NO. I

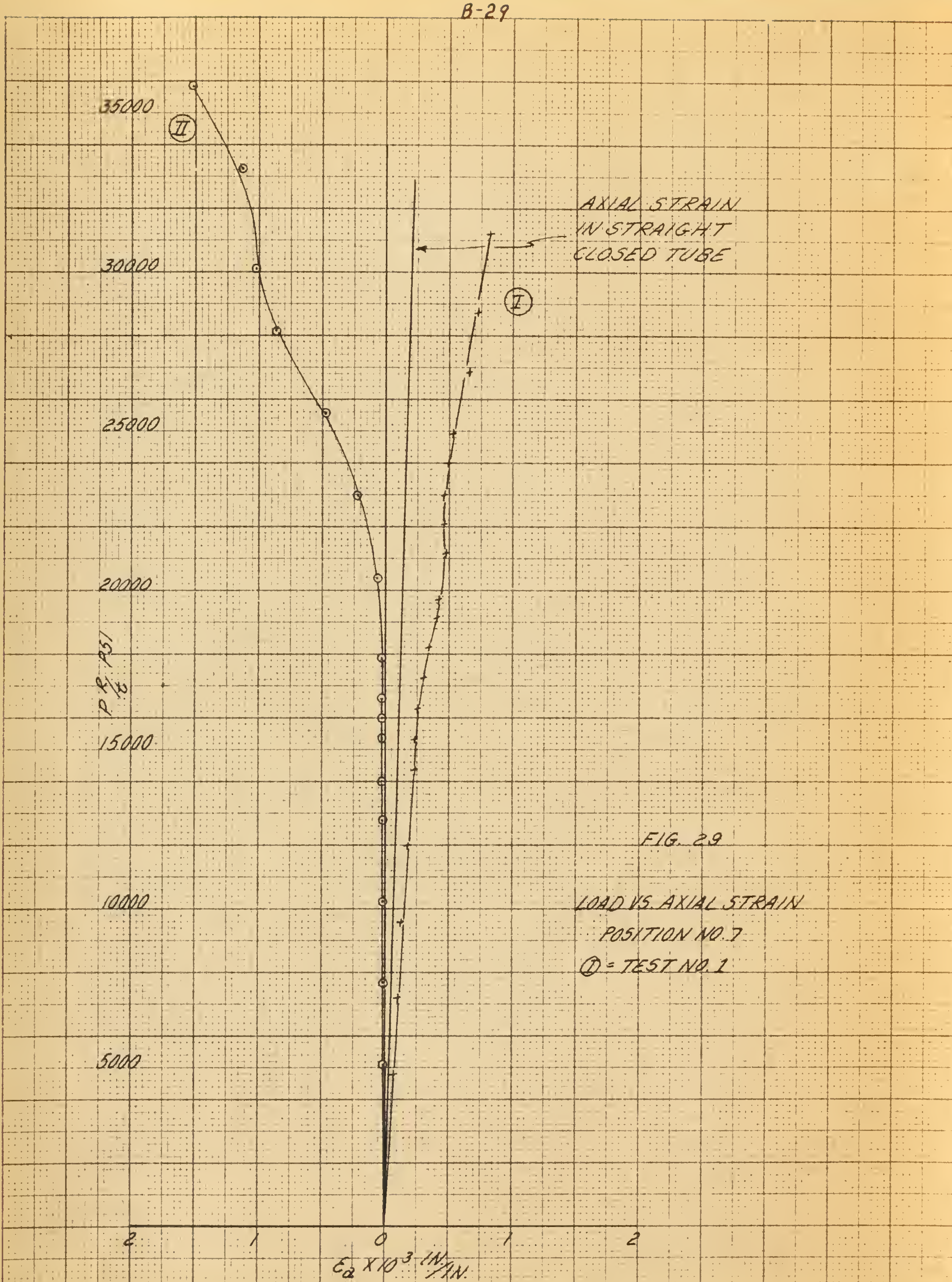
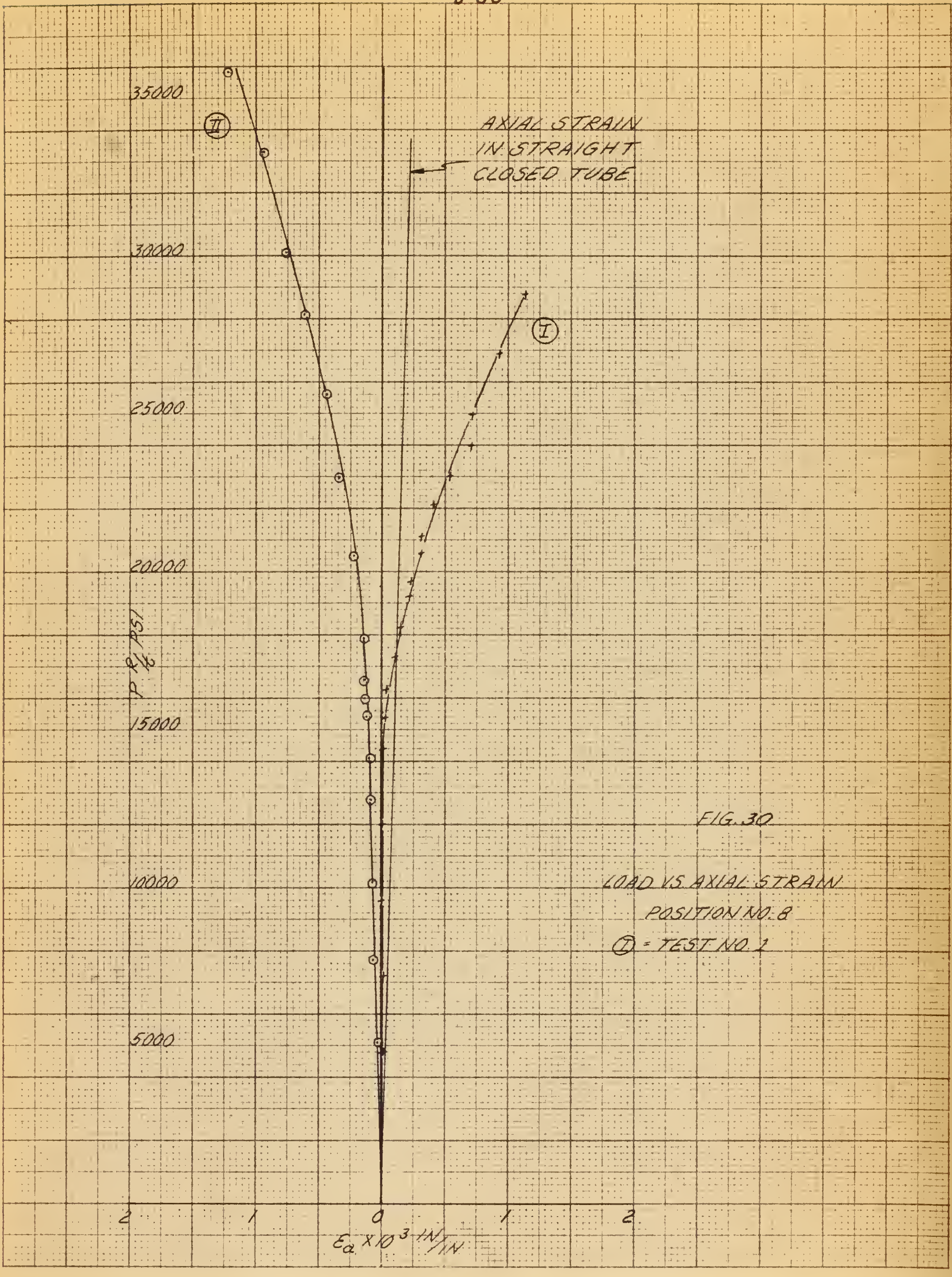


FIG. 29

LOAD VS. AXIAL STRAIN

POSITION NO. 7

(I) = TEST NO. 1


35000
30000
25000
20000
15000
10000
5000
P R/t PSI
II
I
AXIAL STRAIN IN STRAIGHT CLOSED TUBE
2
1
0
1
2
$\varepsilon_a \times 10^3$ IN/IN
FIG. 30
LOAD VS. AXIAL STRAIN
POSITION NO. 8
I = TEST NO. 1

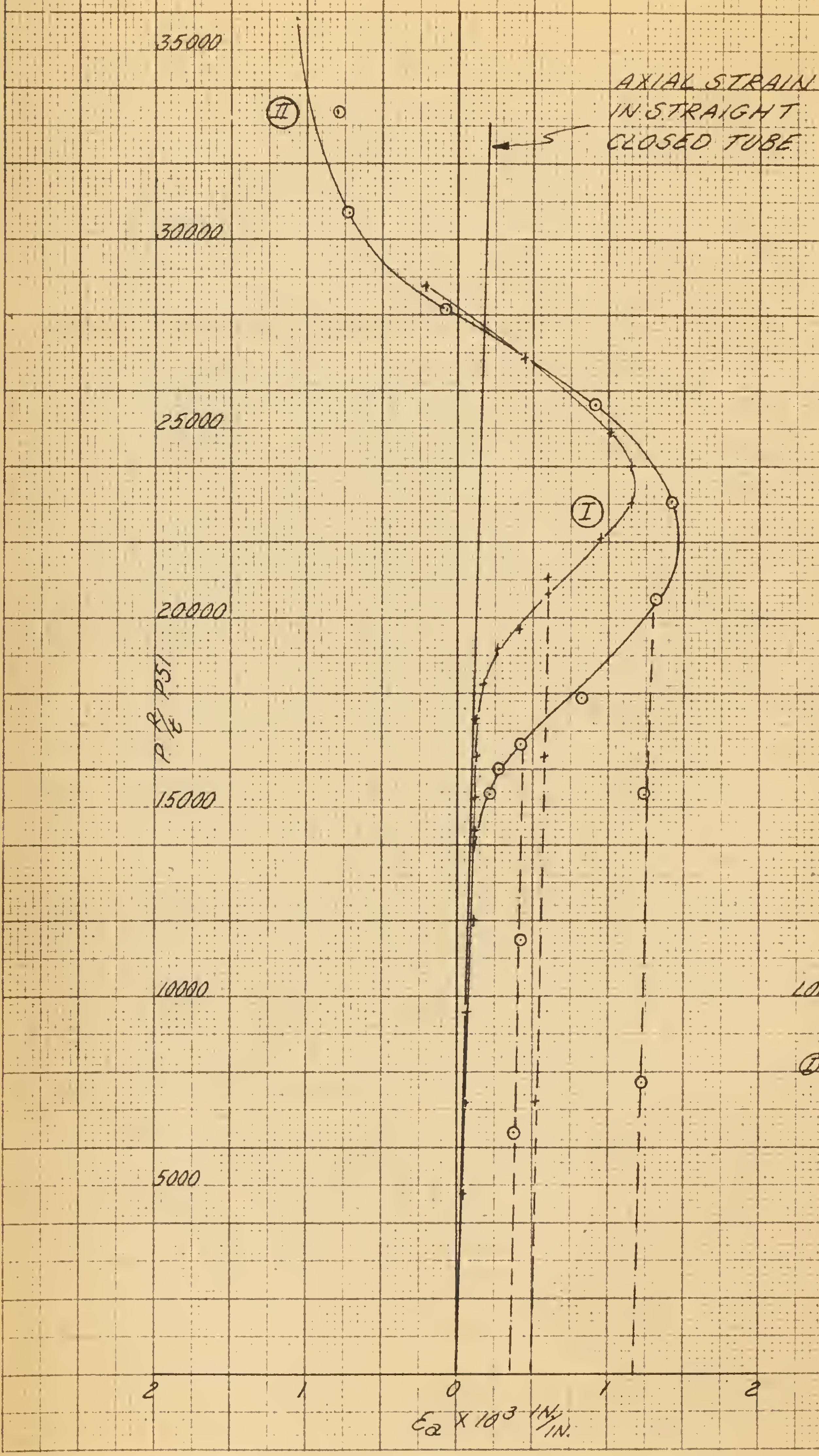


FIG. 31

LOAD VS. AXIAL STRAIN
POSITION NO. 9
① = TEST NO. 1

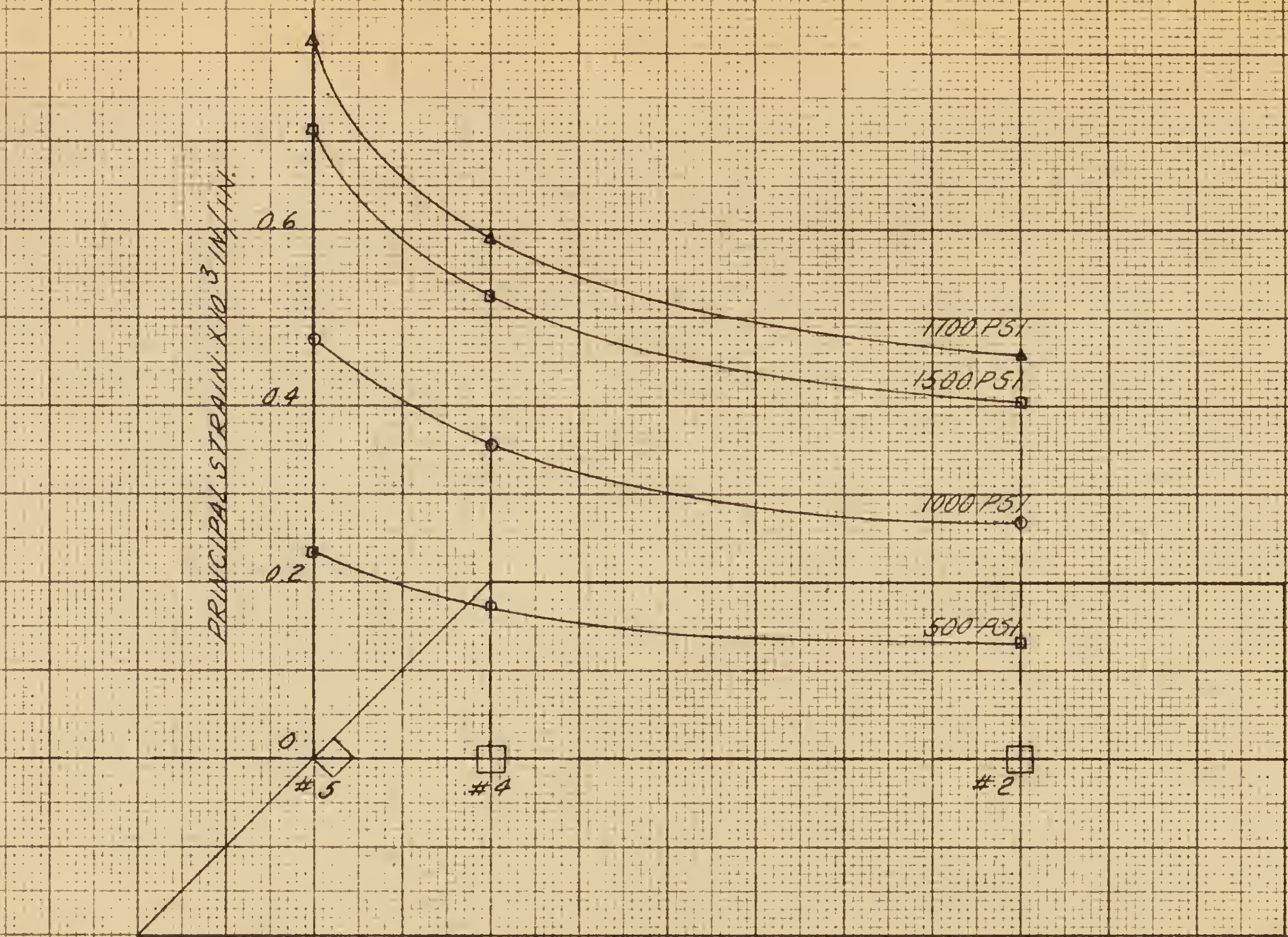


FIG 32

PRINCIPAL STRAIN VS AXIAL POSITION

TEST NO. I

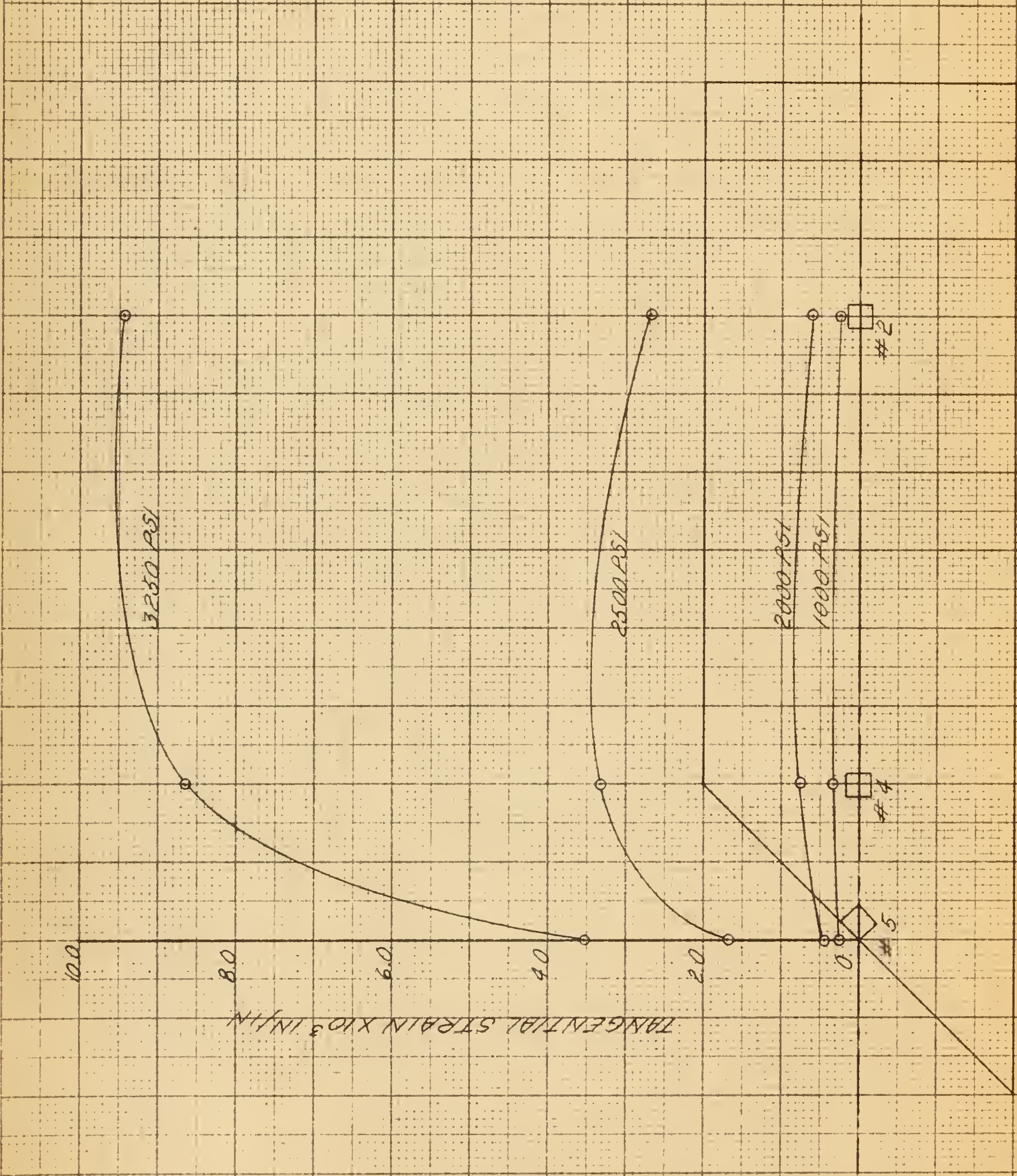


FIG. 33
TANGENTIAL STRAIN VS. AXIAL POSITION
TEST NO. I

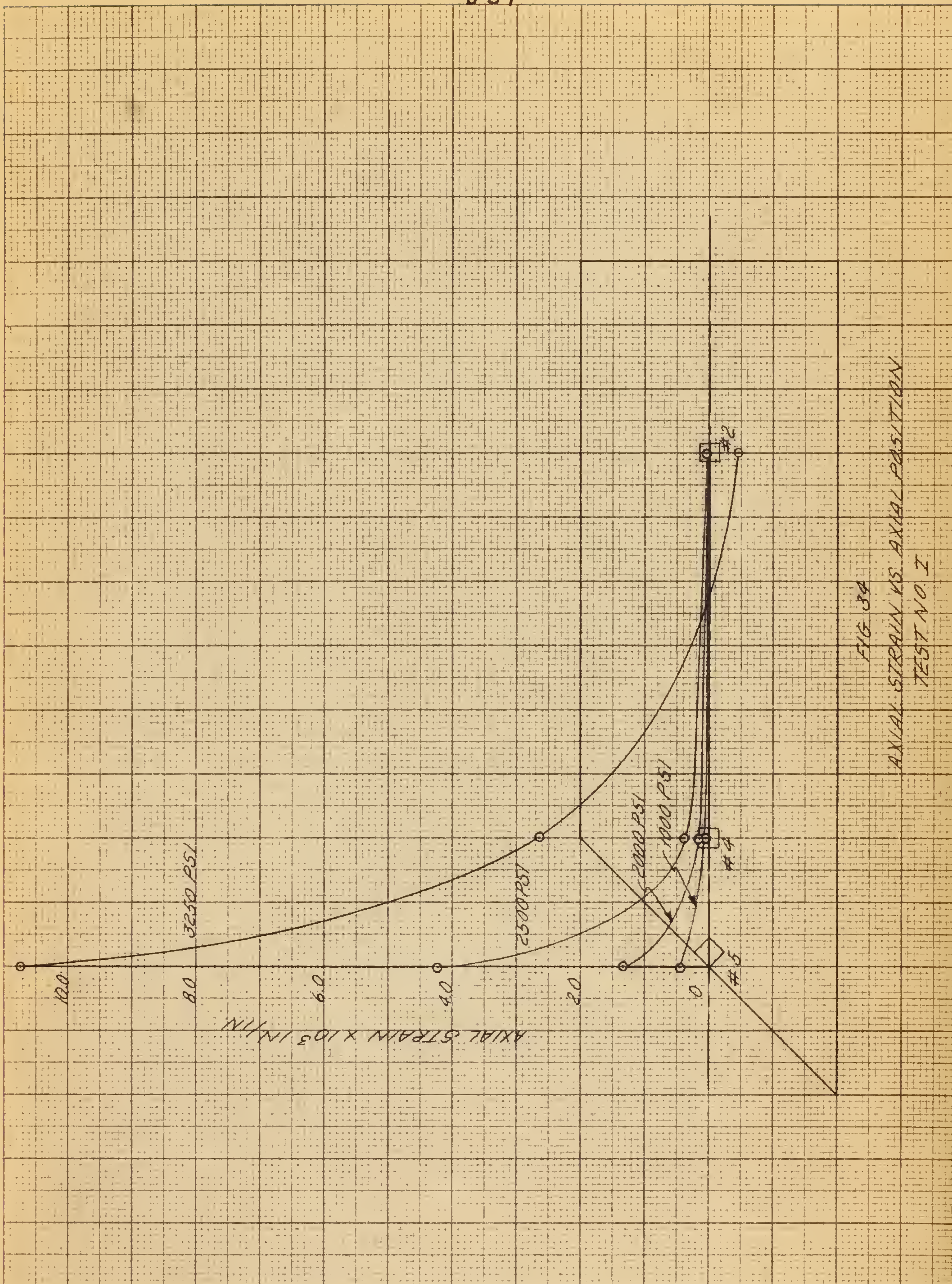


FIG 34
AXIAL STRAIN VS AXIAL POSITION
TEST NO I

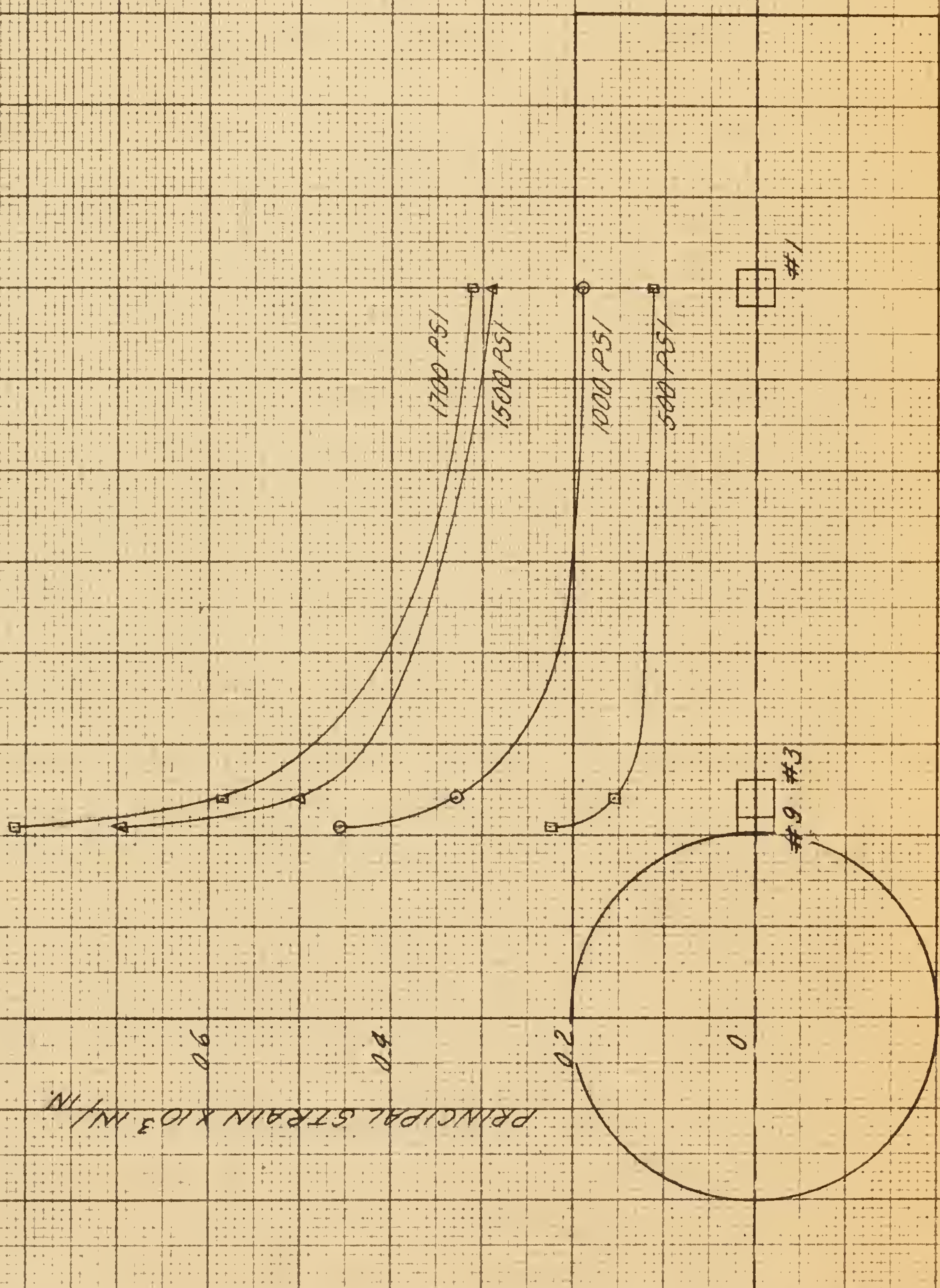


FIG. 35
PRINCIPAL STRAIN VS AXIAL POSITION
TEST NO. I

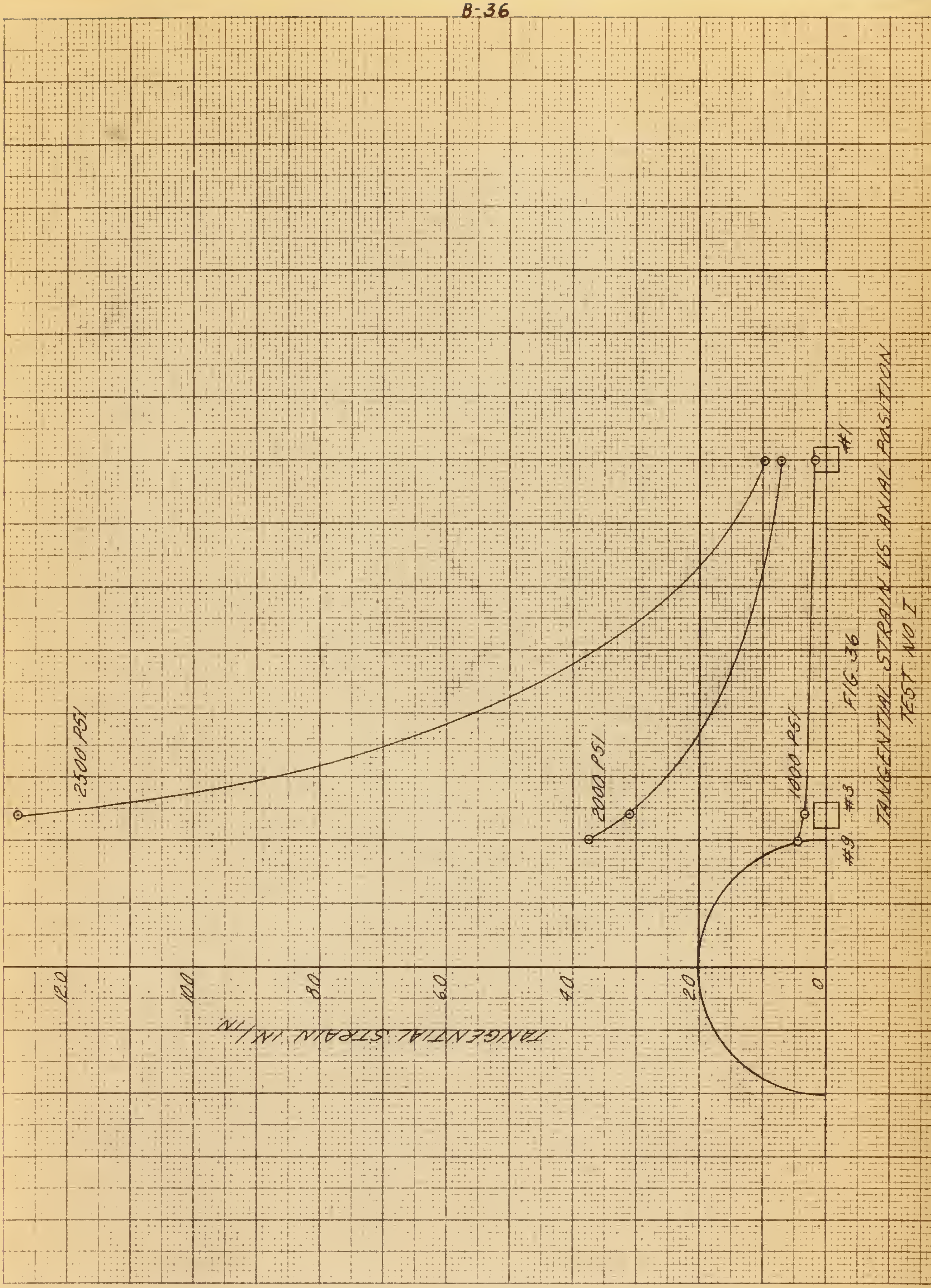


FIG 36
TANGENTIAL STRAIN VS AXIAL POSITION
TEST NO I

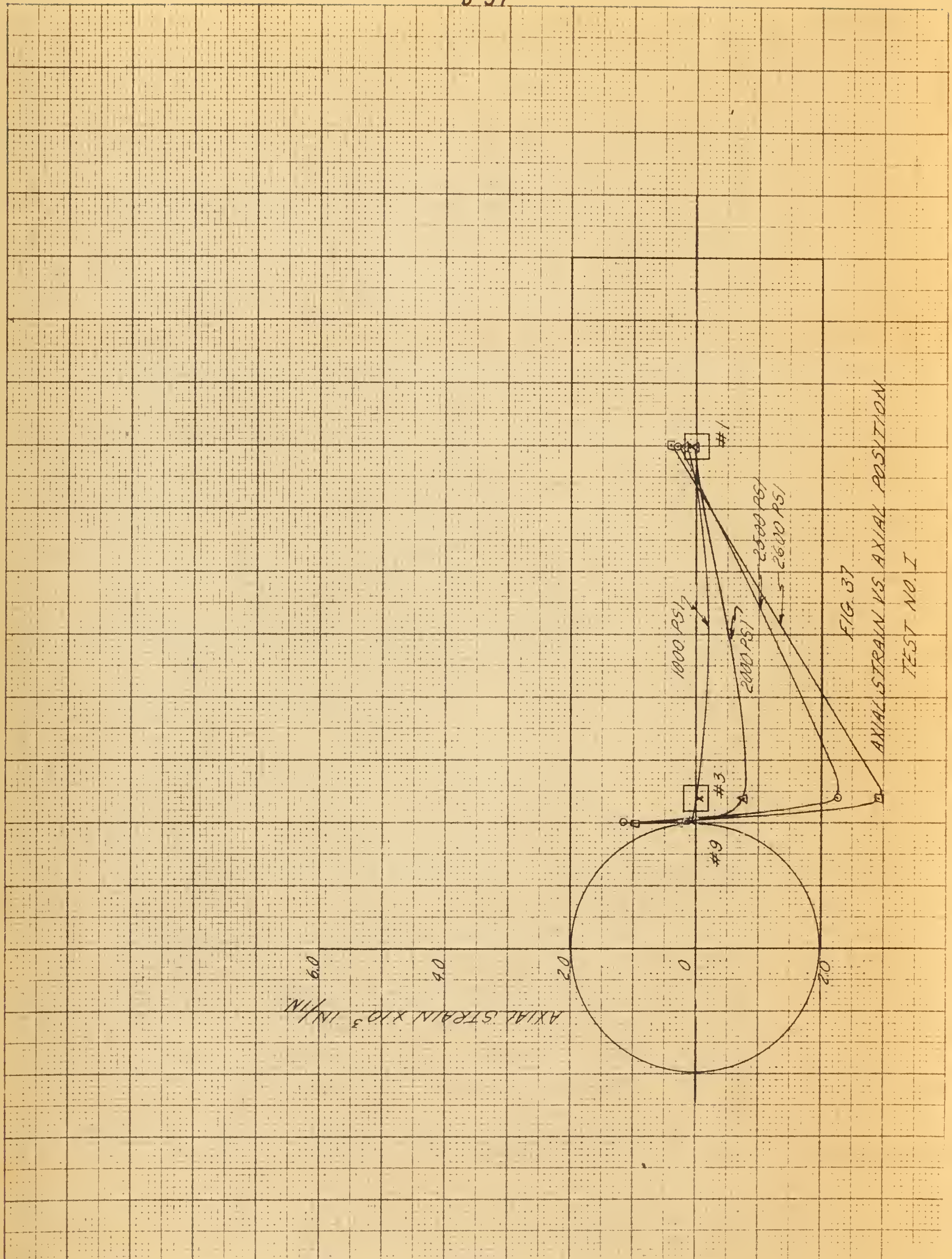


FIG. 37
AXIAL STRAIN VS AXIAL POSITION
TEST NO. I

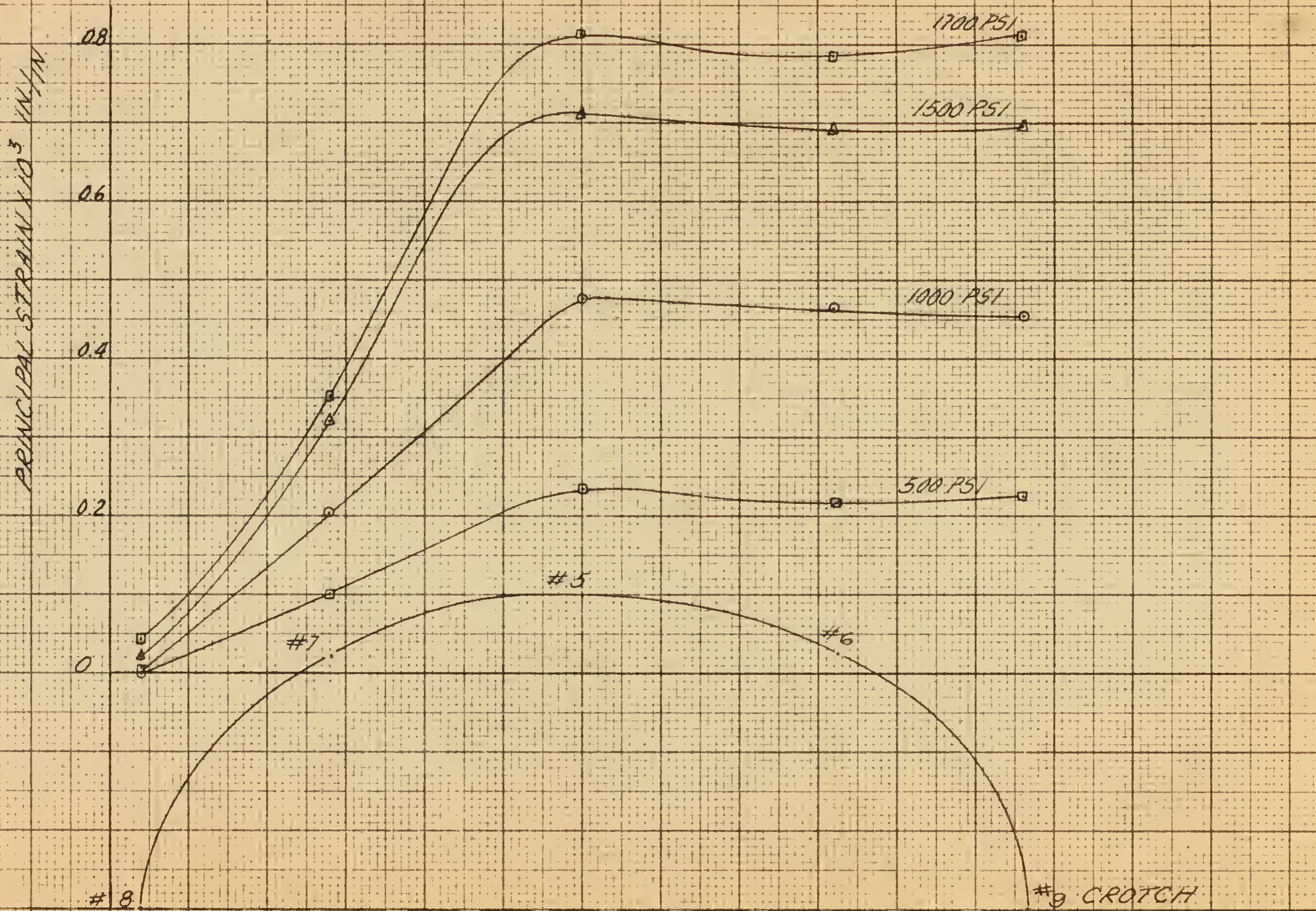


FIG. 38
PRINCIPAL STRAIN VS POSITION ON INTERSECTION
TEST NO. I

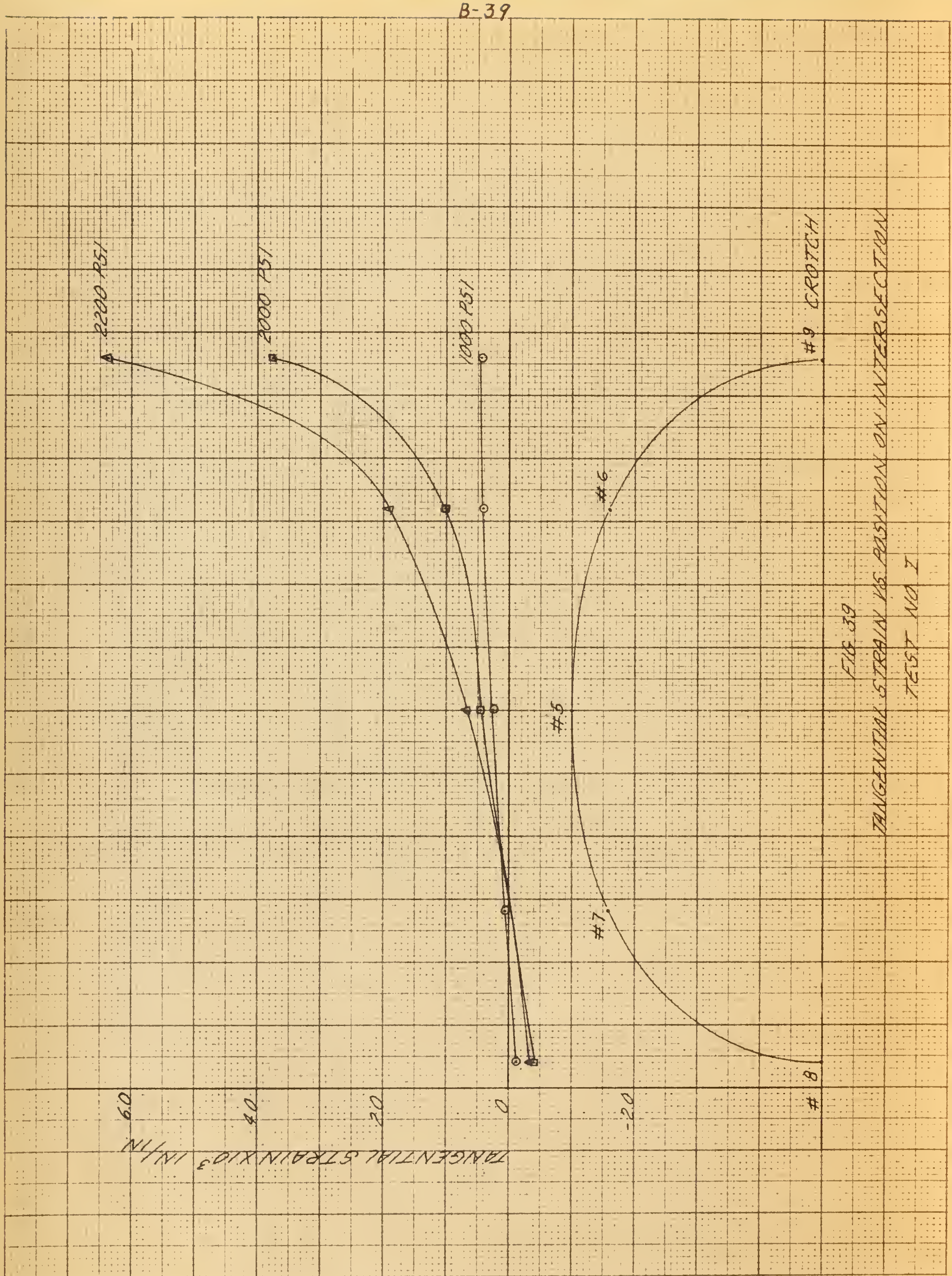


FIG. 39
TANGENTIAL STRAIN VS POSITION ON INTERSECTION
TEST NO I

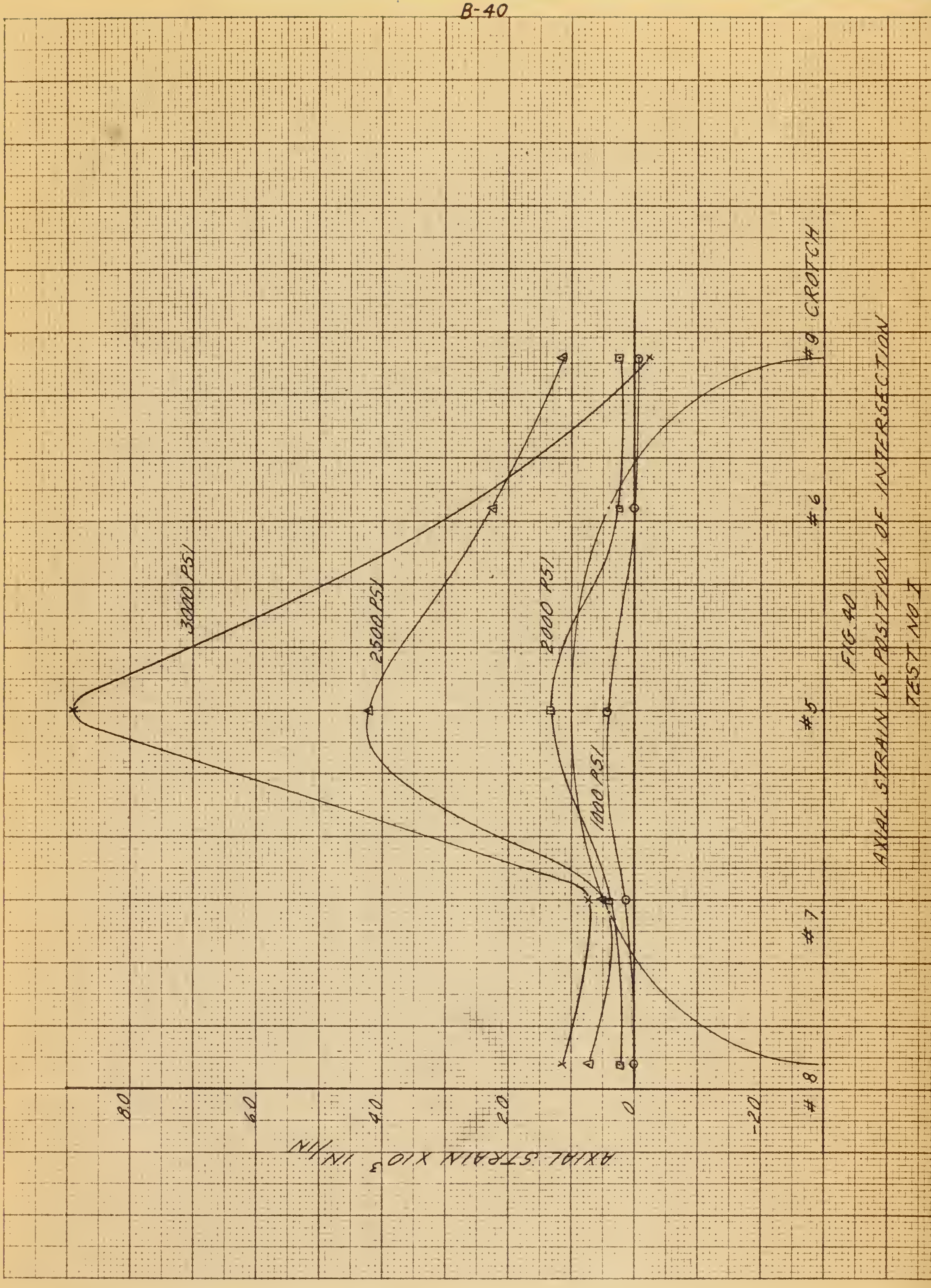


FIG 40
AXIAL STRAIN VS POSITION OF INTERSECTION
TEST NO I

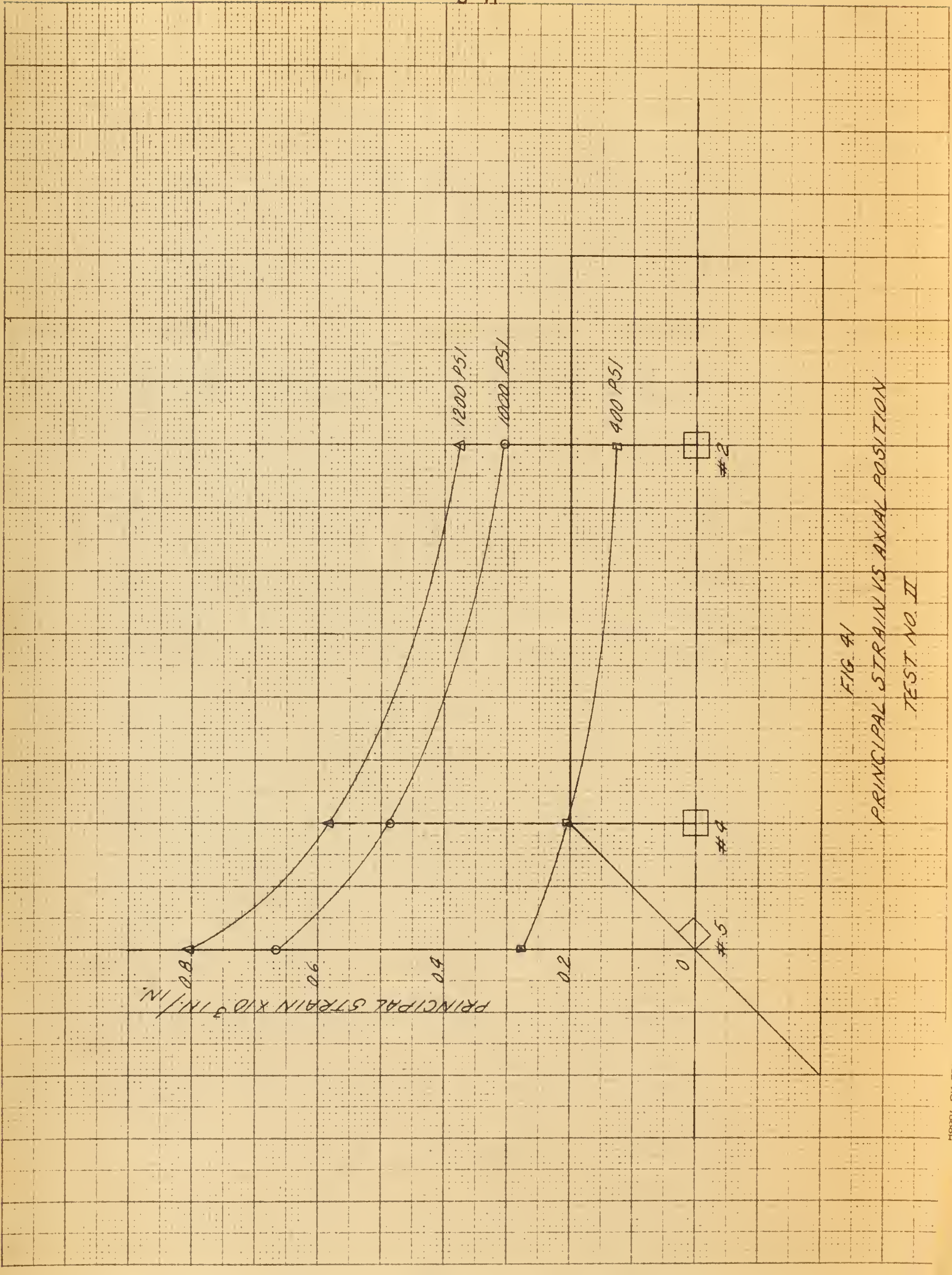


FIG. 41
PRINCIPAL STRAIN VS AXIAL POSITION
TEST NO. II

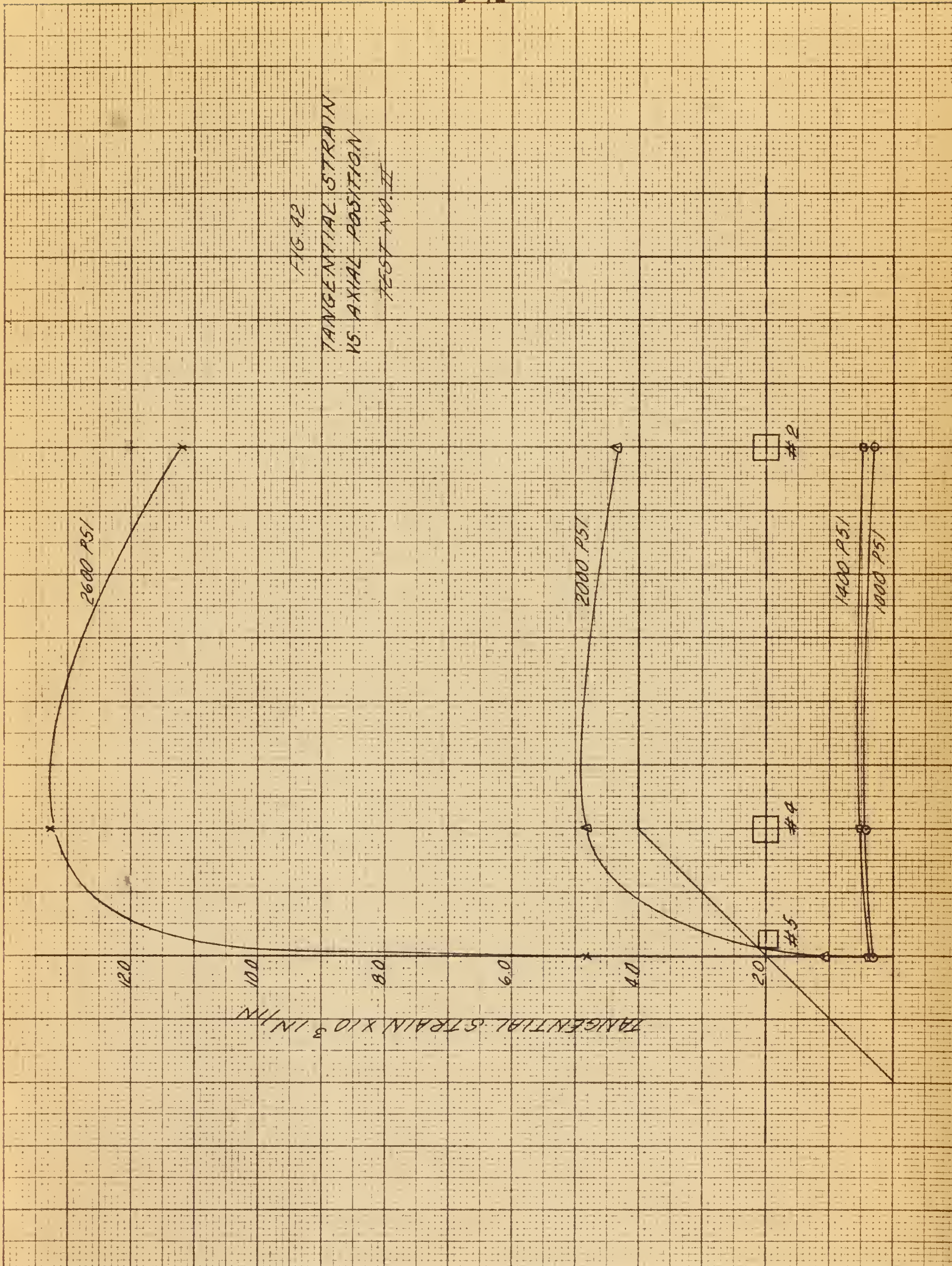


FIG. 42
TANGENTIAL STRAIN
VS. AXIAL POSITION
TEST NO. II

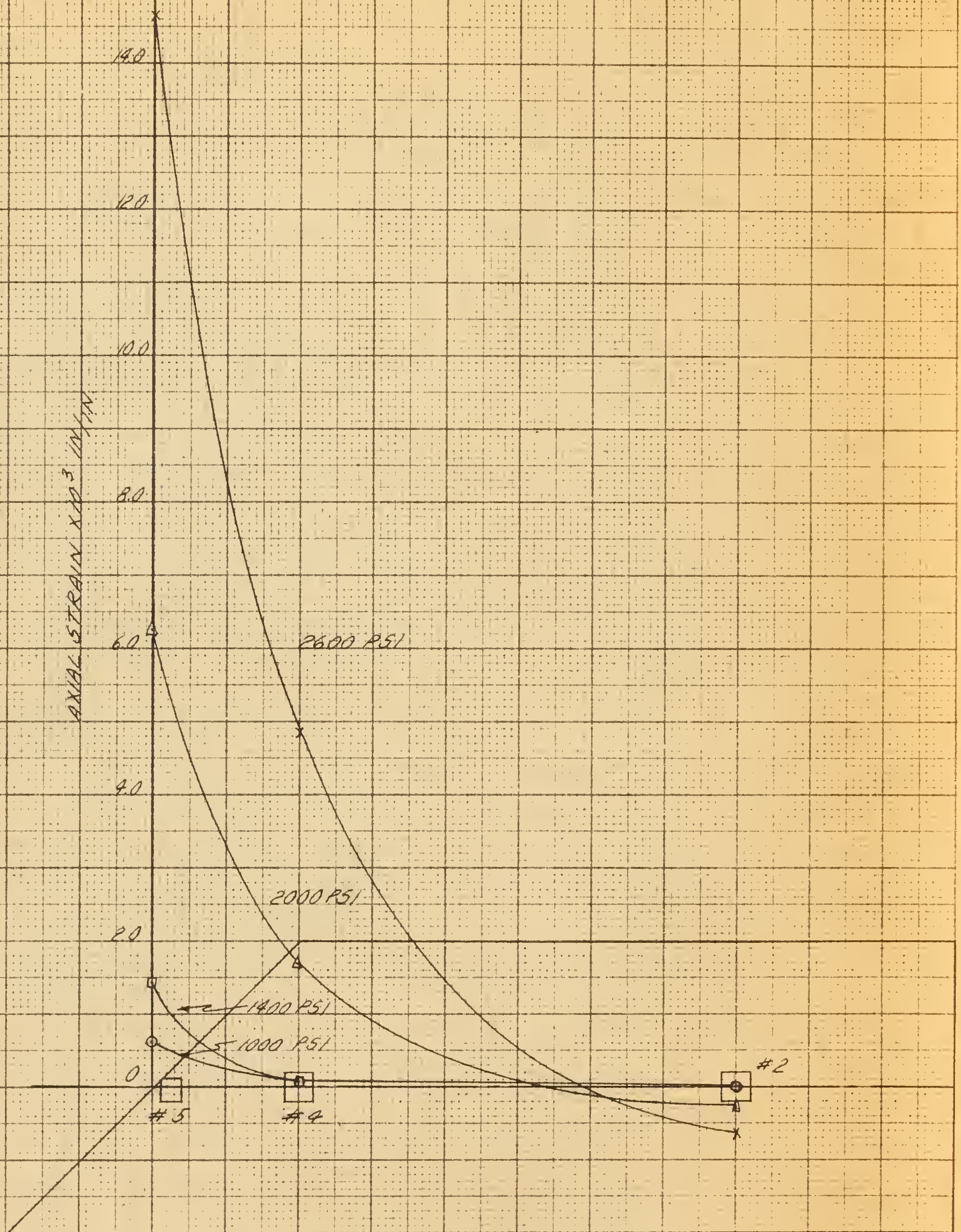


FIG. 43

AXIAL STRAIN V.S. AXIAL POSITION

TEST NO. II

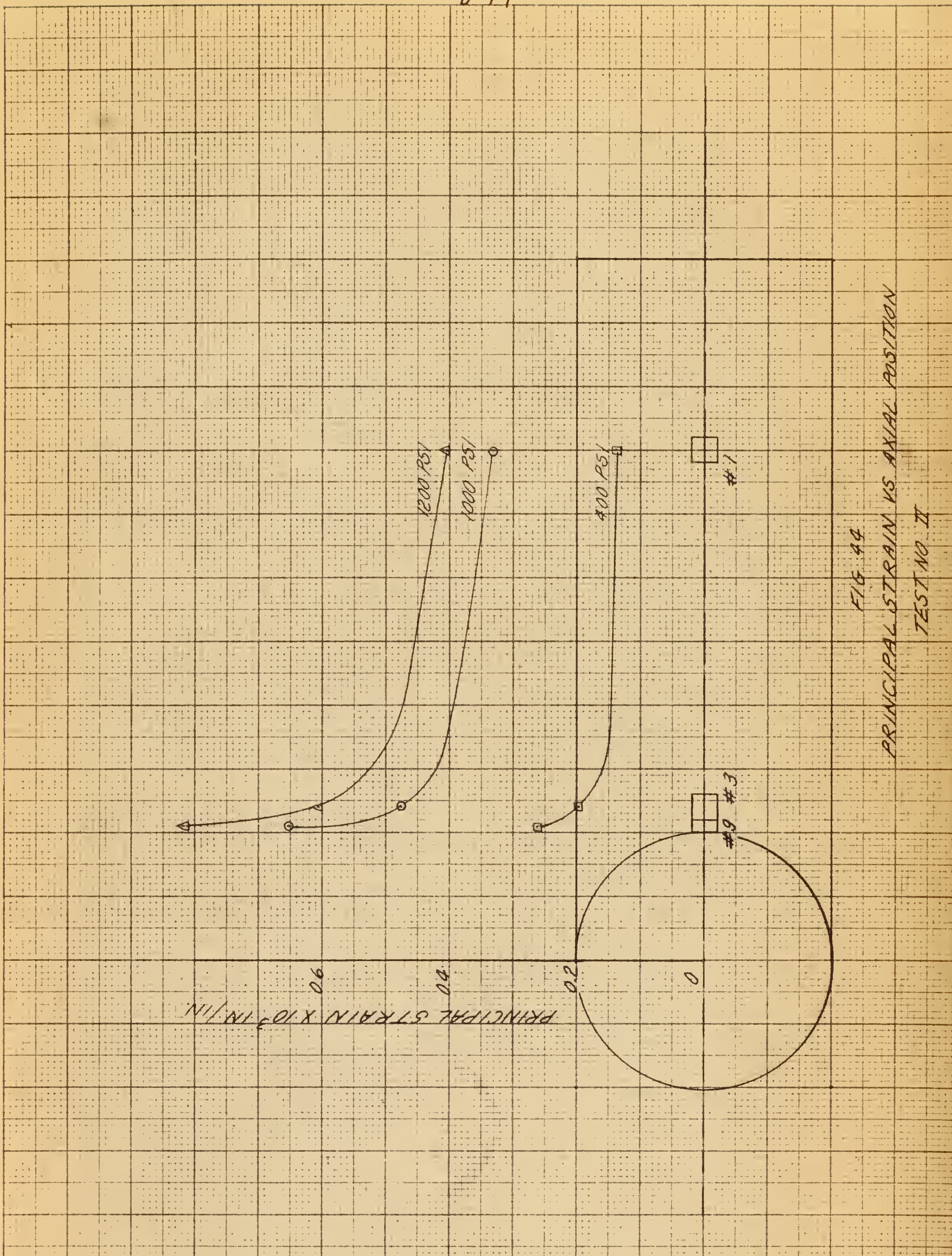


FIG. 44
PRINCIPAL STRAIN VS AXIAL POSITION
TEST NO II

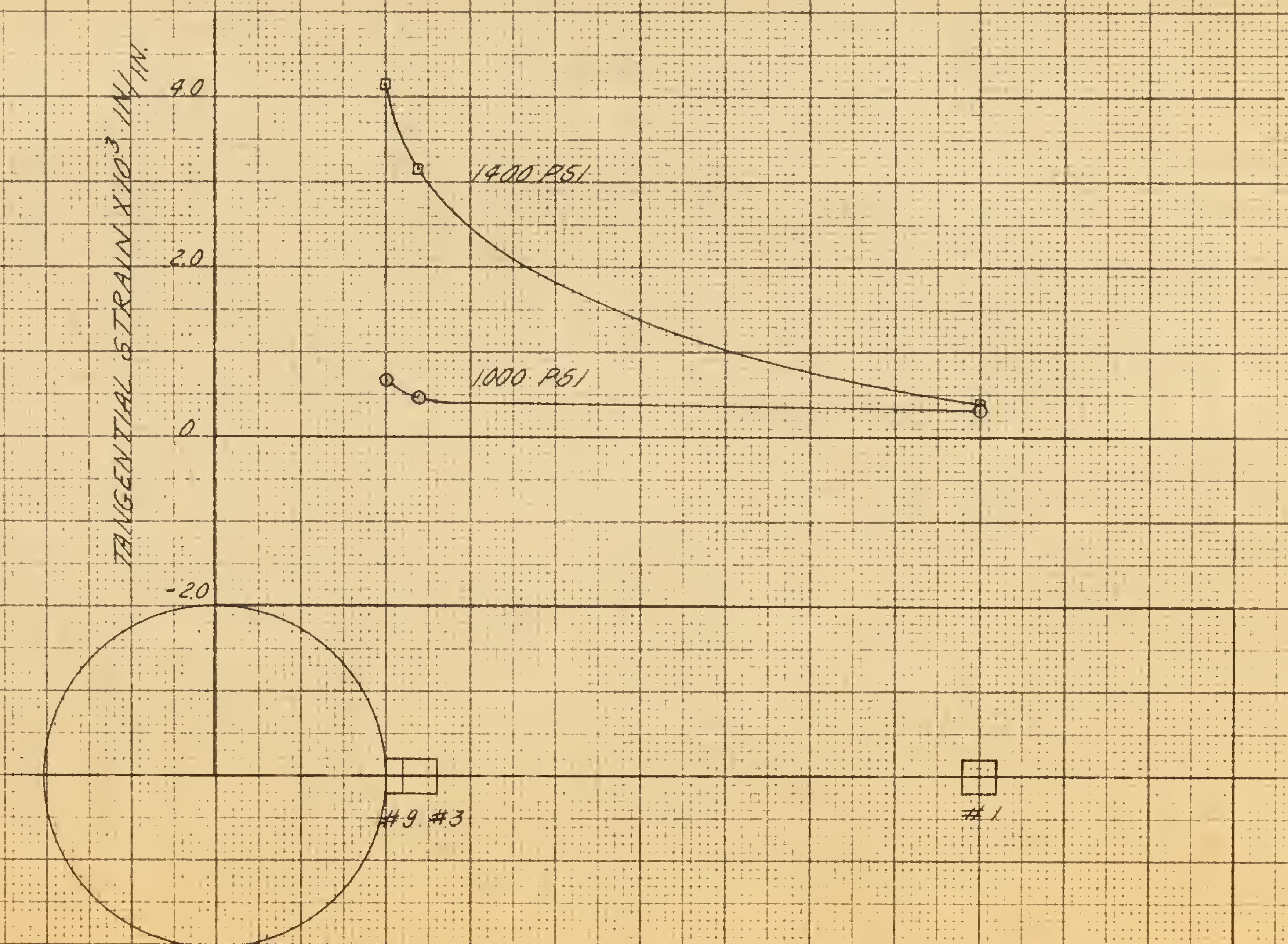


FIG 45
TANGENTIAL STRAIN VS AXIAL POSITION
TEST NO II

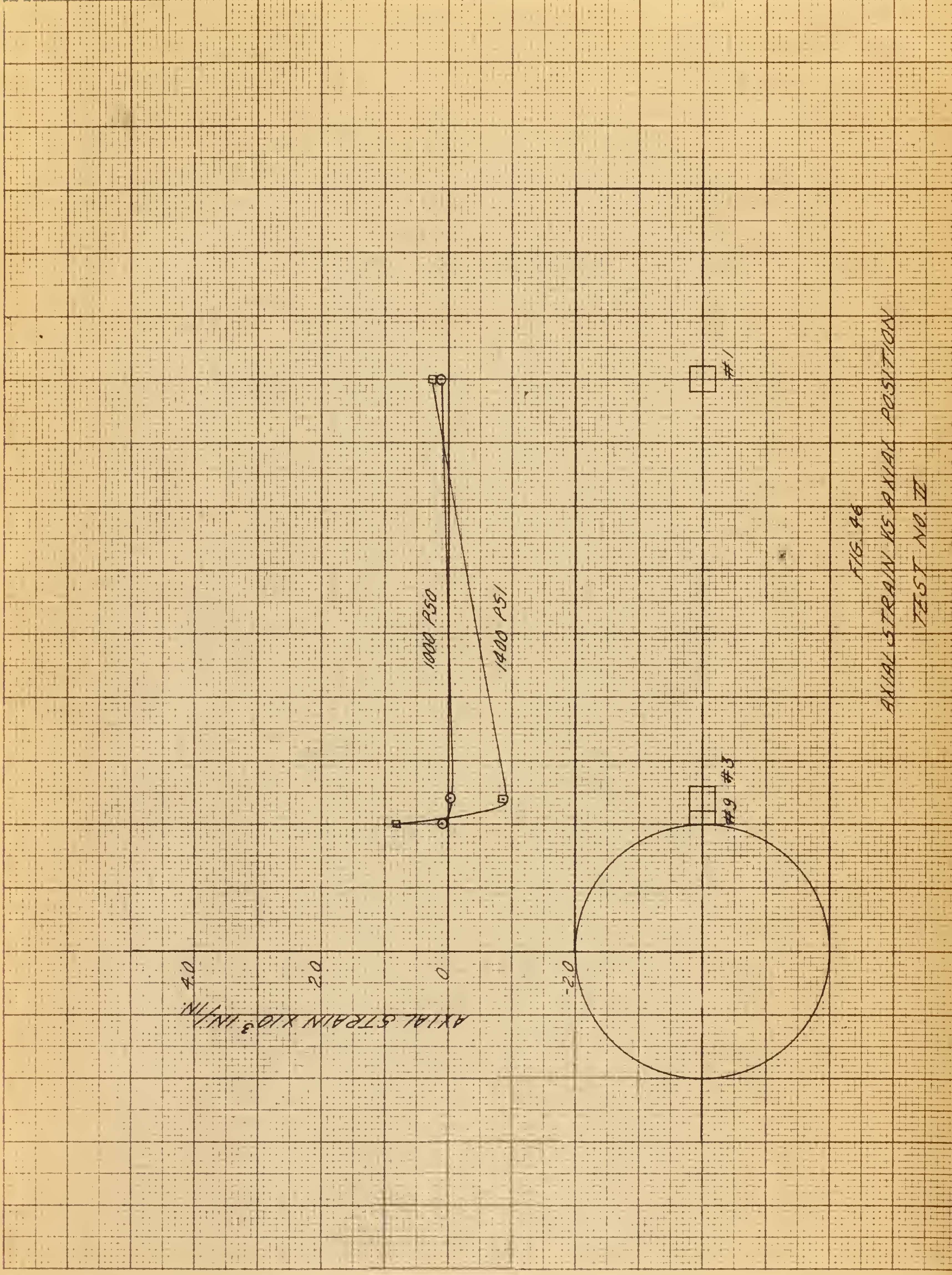


FIG. 46
AXIAL STRAIN VS AXIAL POSITION
TEST NO. II

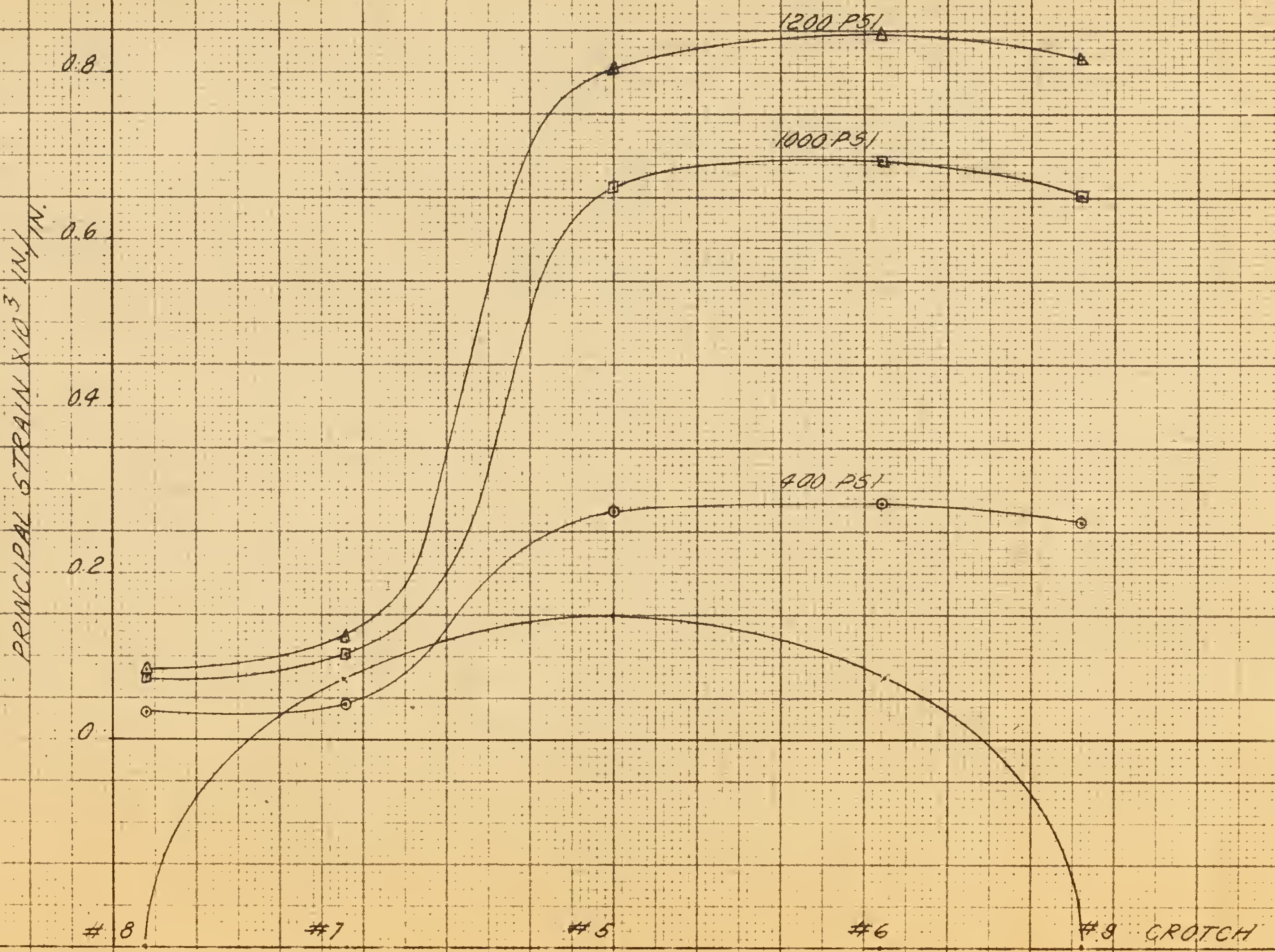


FIG. 47

PRINCIPAL STRAIN V.S. POSITION ON INTERSECTION

TEST NO. II

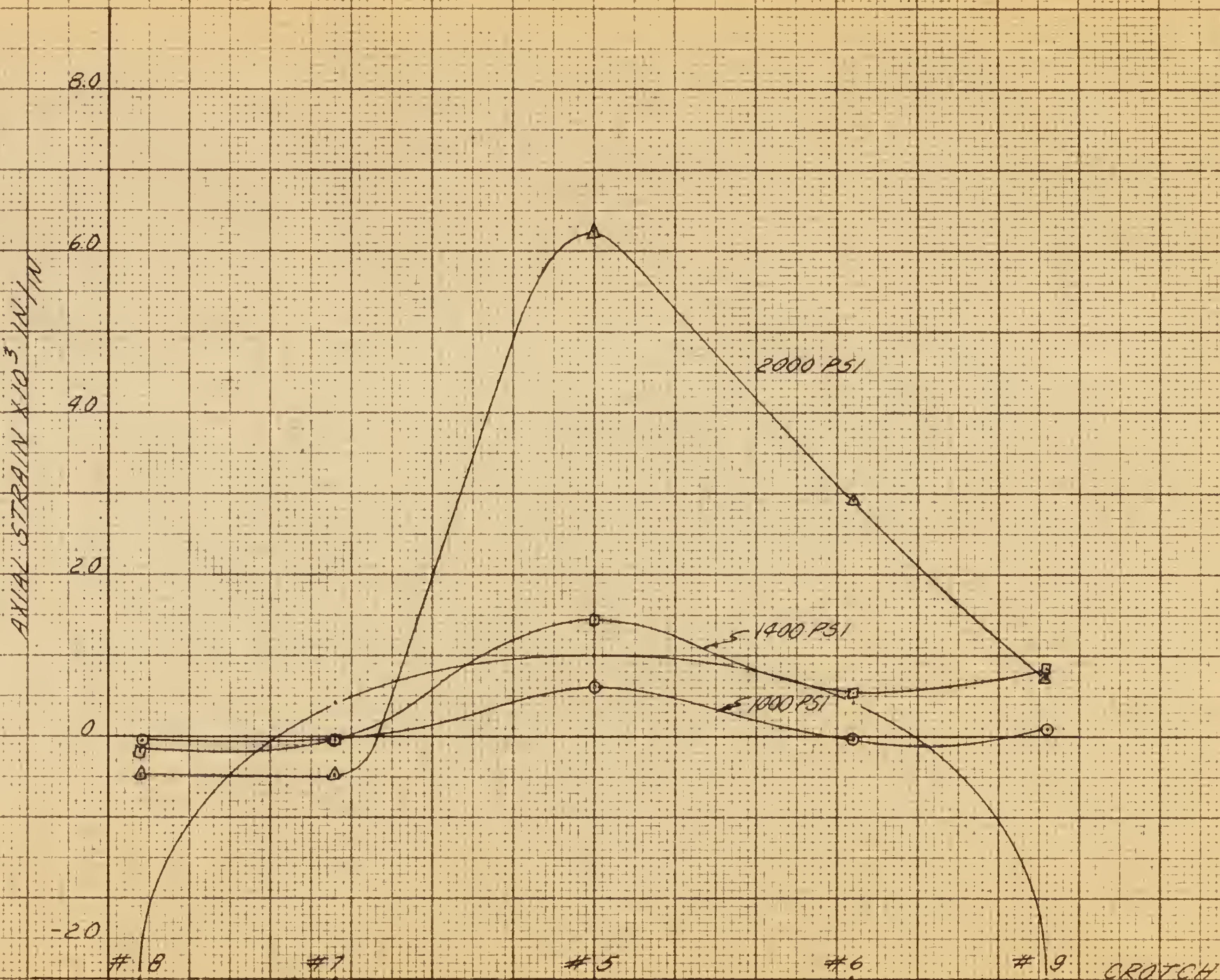


FIG 48
AXIAL STRAIN VS POSITION ON INTERSECTION
TEST NO. II

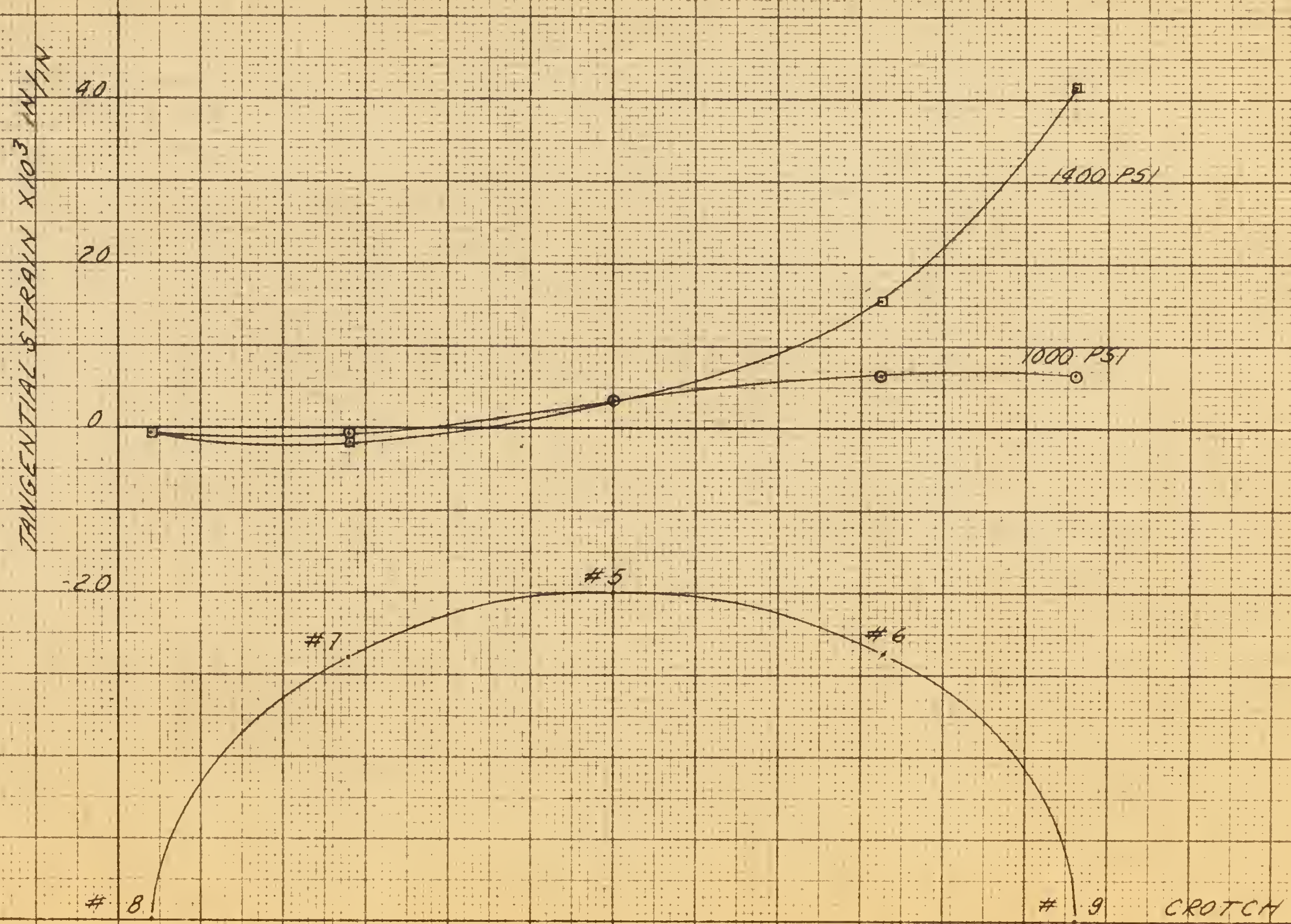
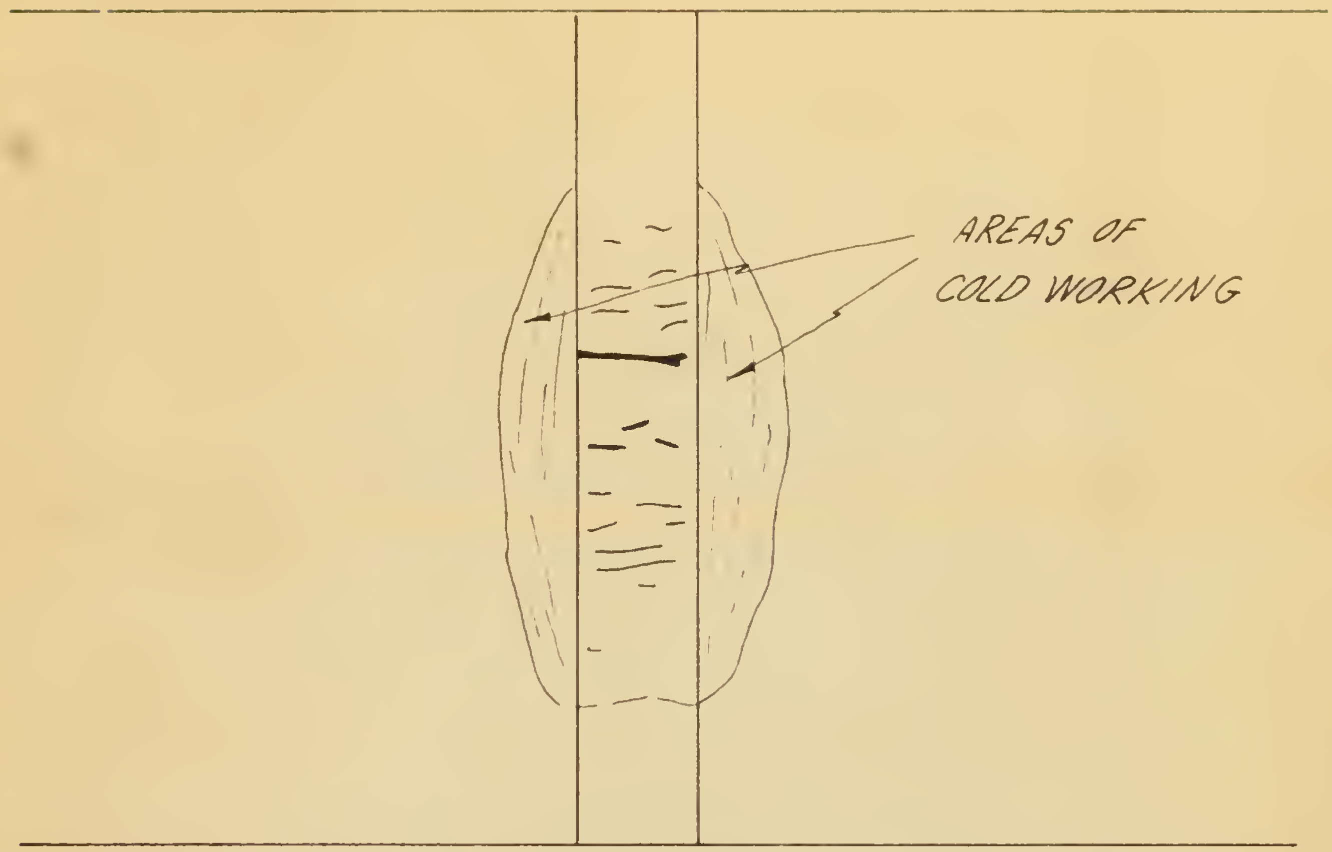


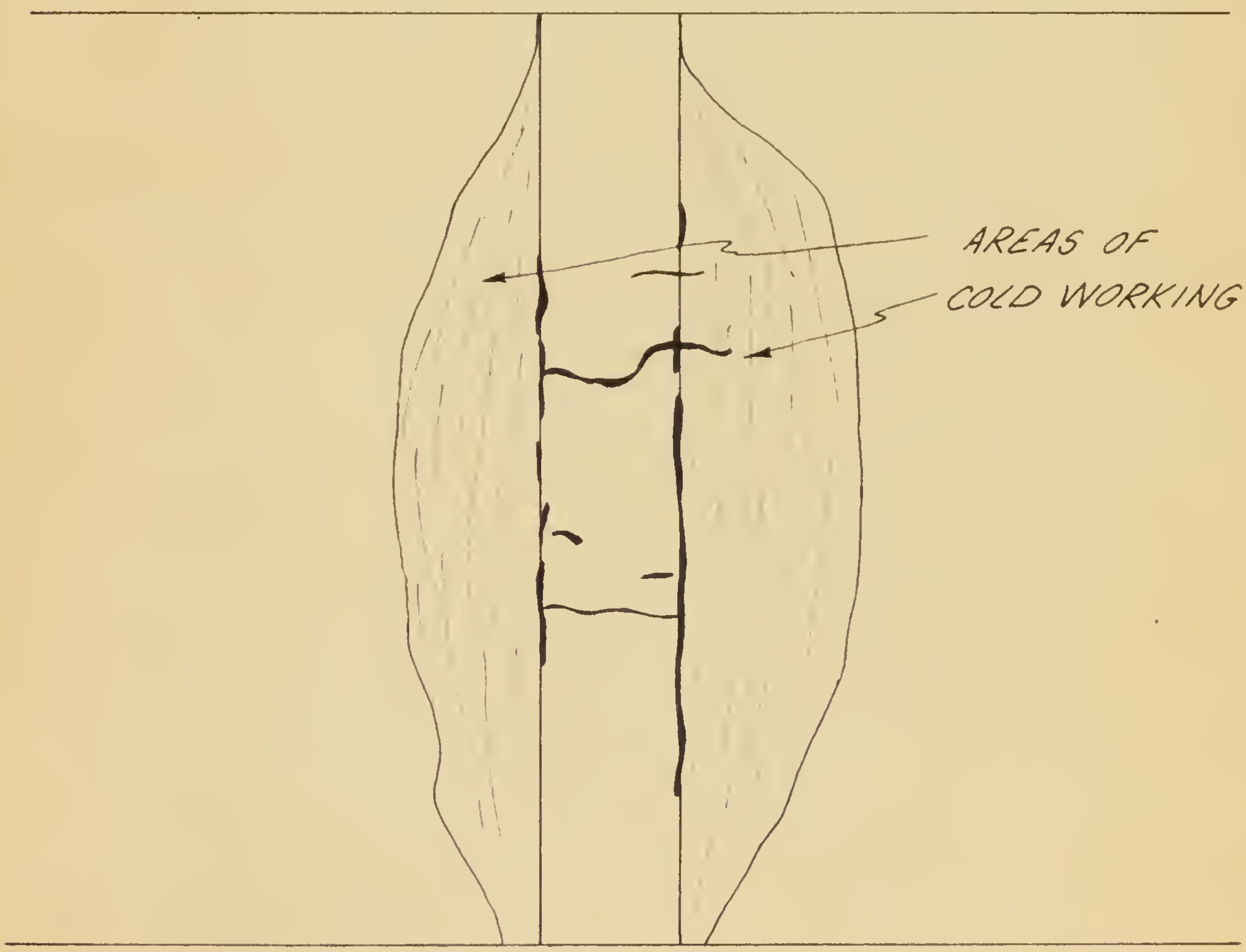
FIG. 4.9

TANGENTIAL STRAIN VS POSITION ON INTERSECTION

TEST NO. II



I



II

FIG. 50
SKETCHES OF BREAKS IN WELDS

Thesis 11371
H28 Harmon
Stress distribution in two circular cylinders intersecting at right angles under the influence of internal pressure.